PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL

U.S. ARMY MATERIEL COMMAND

— COMMITTED TO PROTECTION OF THE ENVIRONMENT —

FINAL ANNUAL GROUNDWATER MONITORING REPORT FOR 1992 ROCKY MOUNTAIN ARSENAL COMMERCE CITY, COLORADO

VOLUME I OF II
AUGUST 3, 1994

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TECHNICAL SUPPORT FOR ROCKY MOUNTAIN ARSENAL

Groundwater Monitoring Program
Final Annual Groundwater Monitoring Report for 1992

Volume I of II

August 3, 1994
Contract No. DAAA05-93-C-0019

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EXECUTIVE SUMMARY

The 1992 Groundwater Monitoring Program (GMP) was established as a one-year transitional program to bridge the gap between the historical Comprehensive Monitoring Program (CMP) and future pre-Record of Decision (ROD) baseline and post-ROD monitoring programs at the Rocky Mountain Arsenal (RMA). Groundwater data collected during the 1992 GMP were obtained to (1) evaluate changes in the extent of contaminant distribution in the Basin F Interim Response Action (IRA) area, (2) monitor the effectiveness of interim remedial actions, and (3) meet regulatory needs.

1992 GMP PROGRAM DESIGN

Water-level and water-quality data collected during the GMP provides information to evaluate groundwater flow and contaminant migration at RMA. These data are collected from networks of monitoring wells in the shallow water-table aquifer (unconfined flow system) as well as the deeper confined Denver Formation aquifer (confined flow system).

The 1992 GMP water-level monitoring network was designed to provide the most efficient areal coverage throughout RMA and offpost areas to evaluate groundwater flows in the unconfined flow system. The network has consistently grown since the inception of the CMP in 1988. The 1992 GMP network included 1,188 to 1,266 wells that were measured during the Winter, Spring, and Summer quarters.

Water-quality sampling for the 1992 GMP was limited to the Basin F IRA area (Sections 23 and 26) to monitor the effects of remedial efforts. The network was designed using the CMP Basin F IRA area monitoring network (Stollar et al., 1990b) as a starting point and then modifying that network. The entire Basin F IRA network (61 wells) was originally scheduled to be sampled during the Winter quarter. A subset of this network was subsequently sampled during the Spring (18 wells) and Summer (29 wells) quarters and additional samples were collected during the Summer quarter.

Water-quality data collected by Morrison-Knudsen Engineers (MKE) were obtained to evaluate unconfined flow system wells in the vicinity of the North Boundary Containment System (NBCS) and Northwest Boundary Containment System (NWBCS). Both Army-certified and U.S. Environmental Protection Agency (USEPA) methods (SW846) were performed for these samples during the 1992 fiscal year.

The groundwater samples collected during the 1992 GMP were analyzed for 59 target analytes including both organic compounds and inorganic constituents. The target analyte list for the 1992 GMP was the same as for the 1990 and 1991 CMP. Approximately eleven percent of the total samples collected were analyzed by gas chromatography/mass spectrometry (GC/MS) methods to confirm or reject the presence of organic compounds detected by GC techniques and to tentatively identify any compounds not among the 59 target analytes. The 1992 GMP analytical program also incorporated a quality assurance/quality control (QA/QC) program designed to establish technically defensible, consistent, and reproducible sample collection and analysis procedures and data results.

1992 GMP DATA RESULTS

Results from a groundwater data evaluation (Harding Lawson Associates [HLA], 1994) of confined Denver Formation flow system well data were incorporated into the 1992 GMP database to present updated technical information. This data evaluation identified flawed and inconsistent data in the RMA Environmental Database (RMAED) and reclassified 125 confined flow system wells to an unconfined flow system designation. A determination of flow system could not be made with available data for 45 1992 GMP wells, and the wells were placed in an unknown flow system category. Both water-level and water-quality data for the unknown flow system wells were not considered representative of the groundwater system at RMA and data from these wells were not used for interpretation.

Flow system designation changes identified in the groundwater data evaluation study resulted in insufficient areal coverage to produce potentiometric surface maps of the previously defined six uppermost confined water-bearing zones. The discontinuous and variable nature of Denver Formation permeable strata also creates difficulty in contouring potentiometric surfaces over extensive areas. For the 1992 GMP, the data is grouped into either an unconfined or a confined flow system.

Water-level data were used to provide information on groundwater flow at RMA. The general configuration of the regional water-table remained similar to that shown during the 1991 CMP and previous monitoring years. This consistency indicates that regional groundwater flow patterns have also remained fairly constant. The regional direction of groundwater flow is from southeast to northwest and generally follows the slope of the bedrock surface. Deviations from the regional flow direction occur along the north boundary, northwest boundary, and in the

vicinity of the Irondale Containment System (ICS). Flows in these areas have been modified by operation of the containment systems.

Potentiometric data from both confined and unconfined flow system wells were used to assess potential aquifer interactions between hydrologic zones and flow systems. These data show that downward vertical gradients occur in slightly more than half of the unconfined and confined well pairs, the magnitude of which lessens toward subcrop areas. Upward gradients existed in slightly less than half of the unconfined alluvial/Denver Formation well cluster sites.

Water-level data were examined in greater detail in the vicinity of the containment systems. The major hydrologic impacts of NBCS operations on the unconfined flow system in this area includes (1) a local flattening of the water table south (upgradient) of the barrier wall, (2) a steepening of the water table just north of the barrier wall, and (3) localized mounding from operation of recharge wells, and recharge trenches. Seasonal water-level fluctuations in the vicinity of the NBCS were generally less than two feet between the three monitoring quarters. Water-level data demonstrate that a reversal in hydraulic gradient to the south was achieved throughout the length of most of the system during the 1992 water monitoring year.

Limited water-level data were available for confined flow system wells. Available data from two sets of well pairs on opposite sides of the barrier wall show a normal gradient (northward) during the Winter and Spring quarters, and a slight reversal during the Summer event. The slight gradients represent changes that are probably the result of seasonal or normal fluctuations in the data.

The configuration of the water-table in the vicinity of the NWBCS varied slightly among the three monitoring quarters. The general configuration of the water-table remained similar to that shown for the 1991 CMP. Gradients were steep along the northeastern extension due to the high elevation and slope of the bedrock surface in this area. Groundwater flow closely follows the bedrock surface in a northeast to southwest direction that parallels the barrier wall. A general flattening of the water-table was apparent in the central and southwest portion of the wall. Recharge downgradient of the barrier wall was sufficient to produce a reversal in hydraulic gradient along the central portion of the barrier wall during most of the 1992 water monitoring year. A slight gradient reversal was achieved across the hydraulic barrier along the southwest extension. A reversal in hydraulic gradient was not apparent along the northeastern barrier wall extension. The nonreversal in this area reflects the location of the upstream monitoring well on a bedrock high. This well is out of context with the hydrologic system in this

area and the apparent lack of reversal is an artifact of the well location.

The 1992 GMP water-level data exhibited little change in water-table surface configuration between monitoring events in the Basin F IRA area and remained similar to the 1990 and 1991 CMP quarterly configurations and water-table elevations. Water-levels were one to three feet higher in some wells during the Winter quarter as compared to the Spring and Summer quarters. Fluctuations between the Spring and Summer quarters were generally less than one-foot.

The water-table configuration in the vicinity of the ICS was characterized by a mound centered around the recharge wells located along the RMA boundary. The effect of the mound was to produce a reversal in hydraulic gradient to the southeast. The extent and water-level elevations in wells around this mound fluctuated between the three monitoring events. Water-levels were as much as nine feet lower near the center of the mound during the Summer quarter compared to the Spring event. This may be the result of pumping from South Adams County Water and Sanitation District wells in this area.

A detailed assessment of hydrologic conditions at the Basin A Neck Treatment System (BANS) was not possible due to limited available water-level data in the 1992 RMAED for this area. In general the configuration of the water-table and water elevations are similar to conditions shown during the 1991 CMP monitoring events and previous years.

Total quality for the 1992 GMP was measured by field and laboratory quality parameters of precision, accuracy, representativeness, comparability, and completeness. These measurement parameters are based on the application of proper procedures, statistical analysis of error, and documentation of processes.

Quality measurements were calculated for each of the parameters and compared to a known set of acceptable measurements established by the U.S. Department of the Army and U.S. Environmental Protection Agency (USEPA). In general, the 1992 GMP data were within acceptable quality parameter limits (PMRMA, 1993 and USEPA, 1987). An exception is the Winter 1992 dieldrin and fluoride analyses. Many data packages for dieldrin and fluoride results that did not meet the quality criteria were not available and could not be verified. The available dieldrin data packages were reviewed and categorized as Type III samples or "picket fence" analyses. These type of samples contain a significant amount of media and instrument interference that causes the potential for reporting false positive results. Confirmational analyses by gas chromatography/mass spectrometry is an option laboratories may use to

substantiate the presence or absence of a contaminant. Without this confirmation, analytical results classified as Type III samples have the potential of being unrepresentative of the groundwater chemistry. Laboratories for the 1992 GMP did not perform these confirmational analyses. The same dieldrin data set was also affected by field and rinse blank contamination. Dieldrin rinse blank contamination affected five samples. A third check on the data included a historical comparison of the sampled sites. Results from data package reviews, field QC sample, and statistical analysis caused a portion of the 1992 GMP dieldrin data to be unusable.

Data that was determined to be unusable, because it did not meet data quality objectives and quality parameter measurements, were not flagged with additional codes in the RMAED. The QA/QC data assessment that was performed included a condensed validation effort to assess data usability and was not intended to provide complete data validation with appropriate flag codes. The RMAED only includes codes placed by the analytical laboratory and Laboratory Support Division (LSD) at RMA.

A complete QA review of quality parameters requires a comparative analysis of the field and laboratory QC samples. Field QC consists of field, trip, rinse, and duplicate samples. For the 1992 GMP, the results of these QC samples are applied to all the investigative samples collected on the same day as the QC sample.

Results of field, trip, and rinse blank sample analyses exhibited evidence of laboratory and field contamination. Field rinse blank data contained chloroform, dieldrin, and aldrin. The chloroform detections did not affect any usable investigative sample results and may be laboratory artifact contamination. However, dieldrin and aldrin contamination did affect data usability for five samples during the Winter 1992 quarter. Field blank data contained detections of arsenic, cadmium, and zinc. Metal detections in field blanks and associated investigative samples indicated cross contamination and the data was not used. One trip blank contained chloroform and affected the data usability for one investigative sample.

Duplicate data correlated and were comparable. The average Relative Percent Difference (RPD) for the entire duplicate data set was 12 percent. Although no specific guidelines are available, RPDs within 20 percent show good reproducibilty.

GC/MS unknowns were reviewed and classified into chemical groupings. The cyclic hydrocarbon group was the most common designation. No other chemical attachment, such as halogens, were present. The conclusion is that GC/MS unknowns and their relative concentrations do not need further investigation.

The 1992 GMP analytical data were used to evaluate lateral and vertical contaminant migration in the Basin F IRA area. Five analytes were selected for graphical presentation and assessment of contamination distribution. These included diisopropylmethylphosphonate (DIMP), dibromochloropropane (DBCP), dieldrin, chloroform, fluoride, and n-Nitrosodimethylamine (NDMA). These analytes were chosen because they are representative of a range of contaminant mobilities and compound groups present at RMA. Overall variations were assessed by comparing the Winter 1992 analytical data to Winter 1991 and Fall 1989 results and evaluating historical trends though the use of concentration histograms. The Winter 1992 GMP data was posted on Fall 1989 contaminant plume maps. The plume boundaries were not reconfigured for this report due to the limited 1992 GMP sampling network.

The areal distribution of the five analytes in the Basin F area in the unconfined and confined flow system is variable and does not exhibit definitive trends since initiation of Basin F IRA activities. Differences between the 1992 GMP data and the Fall 1989 plume maps are primarily due to the addition of reclassified confined flow system wells to the unconfined flow system sampling network and new data from unconfined flow system wells not sampled during previous monitoring events. Histograms of DIMP, DBCP, and chloroform concentrations generally reflect water-quality conditions that have either declined or not changed significantly since initiation of Basin F IRA activities. The 1992 GMP data for dieldrin is inconclusive due to laboratory QC method problems and potential rinse blank contamination. A number of wells in Section 23 and 26 displayed increases and decreases in dieldrin concentration in no apparent areal pattern. Fluoride data has also historically shown random quarterly fluctuations throughout the Basin F area. For the 1992 GMP, fluoride levels were generally less than or similar to historical data. Changes in the overall fluoride distribution in the confined flow system also remained statistically insignificant.

Analytical data for unconfined flow system wells located north of the barrier wall at the NBCS demonstrate that concentrations of mobile contaminants such as DIMP, chloroform, and DBCP, have decreased significantly since NBCS startup and system operations have been effective in preventing downgradient contaminant migration. Available data for dieldrin, a relatively immobile contaminant, show very low to nondetect levels in downgradient wells in the immediate vicinity of the NBCS.

Analytical data collected in the vicinity of the NWBCS during the 1992 water monitoring year for unconfined flow system wells show that DIMP, DBCP, chloroform, and dieldrin

concentrations downgradient of the NWBCS have either declined or remained unchanged since startup of operations and construction of the barrier wall extension in 1990.

CONCLUSIONS

Groundwater data from the 1992 GMP and other monitoring programs at RMA during the 1992 water monitoring year provided information for evaluating and comparing contaminant migration in the Basin F IRA area and monitoring ongoing remedial/response actions. Significant conclusions based on these data are listed below.

1. Regional groundwater flow conditions have not changed significantly since 1987.

2. The use of a smaller well network limited the assessment of the BANS and the ICS, but was adequate for evaluating the NBCS, NWBCS, and the Basin F IRA areas.

3. Data quality objectives were met for all 1992 GMP reviewed data except Winter 1992 GMP dieldrin and fluoride analyses.

4. Decontamination procedures may have been inadequate for particular chemicals and have been revised for the 1993 GMP and continuing GMP field programs.

5. The 1992 water-quality data and areal contaminant distribution in the Basin F area is generally comparable with historical CMP data and reflect contaminant levels that have either declined or not changed significantly in up or down-gradient wells since initiation of Basin F activities in 1988.

6. Water-quality differences between the Fall 1989 plume contours and the 1992 data are mainly attributed to the addition of reclassified confined Denver Formation flow system wells to the unconfined flow system sampling network. The impact on plume reconfiguration and the correlation of these wells with the contaminated alluvial system is being evaluated for future GMP investigations.

7. A reversal in hydraulic gradient to the south at the NBCS was achieved throughout the length of most the system during the 1992 water monitoring year. Analytical data for unconfined flow system wells located just north of the barrier wall show that NBCS operations have been effective in preventing downgradient migration of the mobile contaminants and dieldrin.

8. Recharge downgradient of the barrier wall in the NWBCS was sufficient to produce a reversal in hydraulic gradient along the central portion of the barrier wall.

1.0 INTRODUCTION

This Annual Groundwater Monitoring Report was prepared by Pacific Western Technologies, Ltd (PWT) for the Program Manager for Rocky Mountain Arsenal (PMRMA) as a work requirement for the Groundwater Monitoring Program (GMP), Contract No. DAAA05--93-C-0019 between PWT and the U.S. Department of the Army (Army). Section 1.0 provides an overview of site background and discusses the nature and extent of contamination at Rocky Mountain Arsenal (RMA). Historical groundwater monitoring programs at RMA and a discussion of how these programs relate to the 1992 GMP is also included. Section 2.0 summarizes the geologic and hydrologic setting at RMA. The overall GMP strategy, including water-level and water-quality network design, and the analytical and quality assurance/quality control (QA/QC) program is described in Section 3.0. Data results for the 1992 GMP are detailed in Section 4.0. An analysis of the data results by Interim Response Action (IRA) areas is presented in Section 5.0. The Tri-County Health Department domestic well sampling program and data results are summarized in Section 6.0. Terms and references used in this report are listed in Sections 7.0 and 8.0, respectively.

1.1 SITE BACKGROUND

RMA occupies approximately 27 square miles in southern Adams County, Colorado, approximately 9 miles northeast of downtown Denver (Figure 1.1). RMA was established by the Army in 1942 to produce chemical and incendiary munitions for World War II. Following World War II, the production of munitions decreased, and the Army leased selected portions of RMA to private industry. A chronological summary of activities at RMA follows.

From 1942 until 1957, chemical agents were manufactured at RMA. Levinstein mustard (H) was produced in the South Plants manufacturing area from 1942 until 1950. This area was also used to fill shells with the chemical agent phosgene or incendiary mixtures, including napalm and white phosphorous. During this period, obsolete World War II munitions were destroyed by detonation or incineration on RMA. The chemical nerve agent isopropylmethyl fluorophosphonate (Sarin or GB) was produced in the North Plants manufacturing area from 1953 until 1969. From 1970 to 1984, Army activities focused primarily on the demilitarization of chemical warfare materials including incineration of munitions.

In 1947, portions of RMA were leased to private industry. Early lessees included

Colorado Fuel and Iron Corporation (CF&I) and Julius Hyman and Company (Hyman). CF&I produced chlorine and chlorinated benzenes and manufactured dichlorodiphenyltrichloroethane (DDT). Hyman produced several pesticides during this period. In 1950, Hyman added to its lease a number of facilities formerly operated by CF&I. In 1952, Shell Oil Company (Shell) acquired Hyman and operated it as a wholly owned subsidiary until 1954, when Hyman was integrated into the Shell corporate structure and Shell succeeded Hyman as the named lessee. From 1952 until 1982, Hyman and/or Shell produced a variety of herbicides and pesticides in the South Plants manufacturing complex.

Between 1942 and 1982, a variety of the contaminants associated with the industrial activities onsite were released to the environment at RMA. Chemical waste effluents were discharged into lined and unlined evaporation basins, and solid wastes were buried. Wastewater, raw materials, and end products were leaked and accidentally spilled within the manufacturing complexes, storage areas, and transportation routes on RMA. Chemical products that were not manufactured to specification were commonly discharged into shallow trenches. Munitions were demilitarized and disposed in trenches and on the surface. The sites that are believed to have been the primary groundwater contamination source areas at RMA are the manufacturing complexes, wastewater storage and evaporation basins (Basins A, B, C, D, E, and F), areas of solid waste disposal, and the rail classification yard (Figure 1.2).

In the early 1950s, the effects of chemical contamination on the local environment became evident. By 1951, high waterfowl mortality was suspected of being linked to the insecticide contamination of three lakes on RMA (Armitage, 1951; Goodall, 1951). In 1954 and 1955, severe crop loss was reported by farmers northwest of RMA using well water for irrigation (U.S. Department of Health, Education, and Welfare, 1965). Two contaminants, diisopropylmethylphosphonate (DIMP), a manufacturing byproduct of the nerve agent GB, and dicyclopentadiene (DCPD), a chemical used to produce insecticides, were detected in offpost surface water in 1974 (R. L. Stollar and Associates, Inc. [Stollar] et al., 1991). Groundwater contaminated with dibromochloropropane (DBCP) and other compounds has been detected in samples from offpost since 1978 (Environmental Science and Engineering [ESE], 1987).

1.2 NATURE AND EXTENT OF CONTAMINATION

Releases of a variety of contaminants to the environment at RMA have resulted in contamination of environmental media both onpost and offpost (Ebasco Services, Inc. [Ebasco],

et al., 1991). This report discusses the impact of such contamination on the medium of groundwater in the RMA area.

The distance that a groundwater contaminant plume extends from its source area depends on numerous factors, including the contaminants' behavior in the environment, the amount and time of the release, and other factors, as noted below. Groundwater contaminant plumes at RMA may extend only a few hundred feet from their sources or may extend miles, as is the case for DIMP. Generally, the occurrence and migration of contaminants in groundwater at RMA is complicated by the following factors:

- Many contaminant sources, some spatially separated, some overlapping
- A variety of release scenarios, including single or repeated spills, continuous or intermittent leaks, discharges to ditches or basins, leaching from trenches, and leaching from or direct contact of groundwater with buried wastes
- Many types of contaminants
- Spatial variabilities in aquifer properties
- Complex interactions between water-bearing zones
- Historical changes in the distribution and quantity of groundwater recharge
- The large size of the site

1.3 SUMMARY OF PREVIOUS GROUNDWATER MONITORING

The RMA Contamination Control Program was established in 1974 to ensure compliance with state and federal environmental laws. After the detection of contaminants in samples collected offsite, the State of Colorado issued three administrative orders in 1975 for RMA to cease and desist in activities that could result in contamination of the environment. In response to the cease and desist orders, the Army initiated regional surface-water and groundwater monitoring programs to assess contamination both onpost and offpost. The efforts were carried out under the direction of the RMA Contamination Control Program with objectives being to evaluate the nature and extent of contamination and to develop a means to control contaminant migration.

The Army established the 360 Degree Monitoring Program to monitor groundwater and

surface water both on RMA and offpost. The program changed in scope several times from its inception in 1975 to its completion in 1984 in response to the geologic, hydrologic, and chemical information obtained and changing groundwater contamination patterns. During this period, the Army performed numerous other contaminant monitoring tasks and initiated groundwater remediation efforts on RMA. Three boundary containment systems, shown in Figure 1.2, were constructed to intercept and remove contaminants from groundwater and recharge the treated water. The North Boundary Containment/Treatment System (NBCS) became operational in 1978 and was expanded in 1981. The Northwest Boundary Containment/Treatment System (NWBCS) became operational in 1984. Both systems contain a soil-bentonite slurry wall, a row of extraction wells upgradient of the slurry wall, a water treatment system, and a series of recharge wells on the downgradient side of the slurry wall. The southwest portion of the NWBCS does not contain a slurry wall, and groundwater contaminants are captured by a hydraulic barrier established with the extraction and recharge wells. The Irondale Containment/Treatment System (ICS) was activated in 1981 on the western border of RMA and includes two rows of extraction wells, a water treatment system, and a line of recharge wells downgradient of the treatment system.

In 1984, the Army awarded a multiyear, multitask remedial investigation/feasibility study (RI/FS) contract that included two tasks pertinent to groundwater monitoring: Task 4 and Task 44. Task 4 included a one-year regional groundwater and surface-water sampling program to assess the nature and extent of contamination at RMA and to develop a litigation-quality database. The Initial Screening Program (ISP) was developed to address the technical elements of Task 4. From September 1985 to February 1986, 380 wells were sampled for the ISP that provided basic water quality information for subsequent Task 4 sampling events. A water-level monitoring network of approximately 850 wells was maintained for the ISP. Task 44 provided for water-level and water quality monitoring to identify areas of potentially significant exposure to contamination.

In 1987, long-term groundwater monitoring was separated from the RI/FS program and included as a single comprehensive program in the groundwater element of the Comprehensive Monitoring Program (CMP). The Transitional Monitoring Program was conducted in 1987 to provide continuity between groundwater monitoring for the RI/FS contract and the CMP.

The CMP was initiated in 1988 and provided long-term monitoring of groundwater and other environmental media, including surface water, air, and biota. The objectives of the CMP

groundwater element were as follows:

- o Maintain a regional and local (project area) groundwater monitoring program to update and verify RI/FS data.
- o Assess and report the amount and extent of contaminant migration and distribution of contaminants both onpost and offpost.

For the 1988 CMP the groundwater element of the CMP included measuring the water level in approximately 1,119 wells on a quarterly basis (Table 1.1). The potentiometric surface of groundwater was mapped for six zones in the Denver Formation. In addition, water quality samples were collected from 466 wells for the annual monitoring network, 307 wells for the semiannual monitoring network, and 46 wells for the quarterly monitoring network. Groundwater samples were analyzed for the 59 target analytes listed in Table 1.2.

During the 1989 CMP, water levels were measured in approximately 1,013 wells on a quarterly basis. The potentiometric surface of groundwater was mapped for six zones in the Denver Formation. In addition, groundwater samples were collected from 488 wells for the annual monitoring network, 388 wells for the semiannual monitoring network, and approximately 50 wells for each of the two quarterly monitoring networks. Groundwater samples were analyzed for the 59 target analytes listed in Table 1.2. Isotopic data for deuterium, oxygen-18, and tritium were collected for a limited number of wells during a pilot program to assess the usefulness of isotopic data to assist in the understanding of the hydraulic connection between the unconfined and confined flow systems.

For the 1990 CMP, water-levels were measured in approximately 1,210 wells on a quarterly basis. The potentiometric surface of groundwater was mapped for six zones in the Denver Formation. In addition, groundwater samples were collected from 621 wells for the annual monitoring network and approximately 60 wells for each of the three quarterly monitoring networks. Groundwater samples were analyzed for the 59 target analytes listed in Table 1.2. Unlike the 1989 water monitoring year, analyses were not performed for isotopes during the 1990 event.

A modification was made to the groundwater sampling networks during the 1990 CMP as a result of assessments of historical trends in analytical data. This assessment indicated that contaminant migration at RMA in areas not currently undergoing IRA or boundary system

cleanups does not change significantly over short time periods of one to two years. The conclusion was made that the frequency of groundwater sampling events could be reduced and still provide adequate contaminant migration assessment. The modification involved changing the annual sampling event (approximately 630 wells) to a biennial (every two years) event with a benchmark well network (approximately 230 wells) to be sampled on alternate years. The benchmark well network is a modification of the former semiannual well network and is a subset of the biennial well network. The benchmark well network allows more frequent (annual) monitoring in selected project areas where interim response actions (IRAs) or other activities have occurred that could cause more rapid changes in contaminant distributions. Project-specific groundwater sampling was conducted to support monitoring in the vicinity of the former Basin F.

1991 was the fourth and final year of the CMP. The 1991 monitoring program consisted of three water-level measurement events and three groundwater sampling events. The three events were conducted during Winter 1990/91 and Spring and Fall 1991. Groundwater samples were collected from the CMP benchmark network, which was modified to include 61 additional offpost wells during Winter 1990/91. Groundwater samples were collected from the Basin F IRA area network during Spring and Fall 1991.

1.4 OVERVIEW OF THE 1992 GMP

The GMP was established during fiscal year 1992 as a one-year transitional program to bridge the gap between the historical CMP and the future pre-Record of Decision (ROD) baseline and post-ROD monitoring programs at RMA. The water-level network used for the GMP was similar to those previously used during the CMP. Water-quality monitoring during the 1992 GMP was not as extensive as previous years. The 1992 water-quality sampling network was limited to the Basin F IRA area, where more detailed information was needed to evaluate the effects of remedial efforts. Separate operational monitoring of groundwater was also conducted in the vicinities of the barrier systems.

The primary objective of the GMP is to provide long-term monitoring of groundwater-quality and hydrology on and near RMA. Data collected as part of the GMP are used to:

1. Monitor the effects of remedial actions;

2. Maintain a database to meet regulatory requirements; and

3. Support the ROD.

1.5 FLOW SYSTEM DESIGNATION CHANGES

This report has incorporated the results of a recent groundwater data evaluation study (HLA, 1994). The evaluation identified inconsistent data associated with confined Denver Formation flow system wells in the RMA Environmental Database (RMAED). The study included an evaluation of 833 wells classified as Denver Formation and/or confined, according to the RMAED or by Morrison-Knudsen Engineers (MKE). The following data for each well was examined:

- Well construction integrity
- Existing water-level data inconsistencies and comparison to historical water-levels
- Groundwater quality data inconsistencies and comparison to historical observations
- Well development data, if available were reviewed for wells of unknown flow system designation considered to have potential well construction problems

The results of these evaluations provided the basis for reclassifying flow system designations for wells in the confined Denver flow system. Results from the groundwater data evaluation indicated that (1) a reclassification of the flow system was necessary for some wells, (2) a flow system designation assigned to some wells is questionable because of conflicting data, and (3) a flow system designation could not be identified because of insufficient data or well construction problems. The results and impact of this evaluation on defining the confined and unconfined flow system for the 1992 GMP data are summarized in Section 4.0.

2.0 HYDROGEOLOGIC SETTING

This section provides a brief overview of the geologic and hydrologic site conditions to develop a framework for understanding the groundwater monitoring system designed for the GMP. A comprehensive description of the geologic setting at RMA has been provided by MKE (1988), and Ebasco (1989b). Groundwater hydrology beneath the site has been described by May (1982) and HLA (1992a).

2.1 GEOLOGY

RMA is located within the Denver Basin, a broad structural depression encompassing northeast Colorado and portions of southeast Wyoming and southwest Nebraska. The Denver basin is a north-south trending asymmetrical syncline with steeply dipping beds faulted against the Colorado Front Range on the west and a gently dipping eastern flank that extends into western Kansas and southwestern Nebraska. RMA is located near the structural axis of the southern portion of the basin where the uppermost geologic units dip less than one degree to the southeast.

The Denver Basin was downwarped during the Laramide Orogeny in Late Cretaceous and Early Tertiary time. Sandstone, siltstone, claystone, and lignite deposited during this period comprise the Fox Hills Sandstone, Laramie Formation, Arapahoe Formation, and Denver Formation (Figure 2.1). These strata overlie approximately 7,000 feet of Cretaceous Pierre Shale. Additional alluvial sediment was deposited over the Denver Formation until the late Tertiary period, when regional uplift and erosion removed most of these sediments, as well as part of the Denver Formation. Subsequently, a variety of Quaternary sediment was deposited at RMA.

The topography at RMA is primarily flat with gently rolling hills, wide plains, and shallow basins. Elevation above mean sea level ranges from 5340 feet in the southeastern part of RMA to 5120 feet in the northernmost portion.

This report only examines the Denver Formation and Quaternary deposits since they contain the principal aquifers in contact with potential contaminant sources within RMA. A claystone layer forms the base of the Denver Formation and provides a confining layer between the Denver Formation and the underlying Arapahoe Formation.

2.1.1 Alluvium

The Quaternary surficial deposits, commonly called the Quaternary alluvium, consist of unconsolidated alluvial, colluvial fill, and eolian (wind-blown) silt and sand. The alluvial and colluvial material is composed of volcaniclastic material and glacial outwash containing cobbles and boulders in a matrix of clay, silt, sand, and gravel. Older coarse-grained alluvial deposits are generally found in areas along the South Platte River and the western part of RMA. Paleochannels eroded into the Denver Formation are also filled with coarse-grained sand and gravel. Younger eolian and alluvial deposits are finer grained than the older surficial deposits and commonly form the uppermost alluvial deposits throughout much of RMA.

The Quaternary alluvium typically ranges from 0 to 50 feet in thickness, but locally fills paleochannels to a depth of 130 feet (May, 1982). The surficial geology at RMA is comprised almost entirely of eolian and alluvial material (Figure 2.2). Eolian deposits occur as a discontinuous thin veneer of fine sand and silt over most of the surficial material at RMA. Bedrock outcrops of the Denver Formation occur in only a few locations.

2.1.2 Denver Formation

The Denver Formation is believed to have originally been approximately 900 feet thick over the RMA area (MKE, 1988), but has been eroded to a maximum of 500 feet thick in the southeastern corner of RMA. The formation thins to the northwest and is absent beneath the South Platte River, where it has been completely eroded. In some areas the upper Denver Formation is weathered and in contact with Quaternary alluvium.

The Denver Formation consists of a series of interbedded shale and claystone layers with discontinuous siltstone and sandstone lenses. The sediments were deposited by low-energy fluvial processes in a continental distal alluvial plain environment. Olive, bluish-gray, and brown colors dominate the upper part of the formation due to erosion of basaltic and andesitic volcaniclastic material. Sandstone lenses are generally tan to brown and show well-defined fluvial channel structures and laterally variable crevasse splay sands and overbank deposits. Lignite beds and carbonaceous shales are also locally present.

Stratigraphic correlation of units within the Denver Formation is difficult because of the discontinuous nature of the sandstone lenses and the lateral variability in thickness and composition of other units. A relatively thick, laterally continuous lignite layer, known as

lignite A, occurs within the South Plants and Basin A area. Lignite A has been used as a marker bed from which all other zones in the Denver Formation have been referenced (Ebasco, 1989b). Denver Formation stratigraphy has been interpreted using this and other lignite layers as marker beds.

The Denver Formation dips slightly to the southeast and the erosional bedrock surface slopes to the northwest. Thus, the stratigraphic units from progressively deeper zones are erosionally truncated to the northwest.

2.2 GROUNDWATER HYDROLOGY

The Denver Basin contains four units above the thick Pierre Shale aquitard that contain significant amounts of water. These include those in the Fox Hills Sandstone, the Laramie and Arapahoe Formations, the Denver Formation, and the Dawson Arkose (May, 1982) (Figure 2.1). The main aquifers affected by previous RMA activities are those in the Quaternary alluvium and the Denver Formation; these are the focus of GMP monitoring efforts.

Groundwater at RMA occurs under both unconfined (at atmospheric pressure) and confined (greater than atmospheric pressure) conditions. The unconsolidated Quaternary alluvium and weathered upper parts of the Denver Formation form a generally continuous groundwater system under unconfined conditions. Stratification and discontinuous clay layers in the alluvium can create localized upward and downward gradients in the alluvial/Denver flow system. Confined conditions exist when confining strata inhibit groundwater interaction between the upper unconfined strata and deeper permeable zones in the Denver Formation. To indicate which conditions are present, the groundwater flow systems at RMA are referred to as the unconfined flow system and the confined flow system.

2.2.1 Unconfined Flow System

Unconfined conditions exist in the alluvium and upper Denver Formation where permeable zones are exposed at land surface or where bedrock subcrops beneath saturated or unsaturated surficial (alluvial) deposits (May, 1982). Consequently, the unconfined flow system is interpreted to be a generally continuous system composed of both alluvium and unconfined Denver Formation zones which consist of sandstone or other relatively permeable material. This interpretation is supported by water-level data which indicate that upper Denver Formation units are often hydraulically connected with overlying alluvium.

The saturated thickness of the unconfined flow system can range from approximately 10 to 70 feet. The greatest thickness occurs within the alluvium-filled paleochannels in the bedrock surface in the northwestern portion of RMA. The saturated thickness of the unconfined flow system is typically less than 20 feet beneath the South Plants area and the waste basins.

In some cases, alluvium-filled paleochannels incised in the bedrock surface provide primary pathways for migration of groundwater contaminants at RMA. Man-made features, such as the chemical and sanitary sewer systems, also may have enhanced migration. Figure 2.3 illustrates areas of unsaturated alluvium and contaminant migration pathway locations.

Regional groundwater flow is to the north and northwest. Deviations to the regional flow direction may occur locally as a result of geologic heterogeneities and manmade features, such as the boundary containment systems. The most pronounced deviation to the regional flow pattern is a groundwater mound in the South Plants area. This mound is approximately 25 feet higher in elevation than the regional water-table surface and coincides with a locally elevated bedrock surface. The most probable reason for the existence of the groundwater mound is the relatively low hydraulic conductivity of the bedrock materials. Local changes in flow direction may also be caused by spatial variations in hydraulic conductivity of aquifer materials. Temporal changes in flow regime have occurred as a result of anthropogenic and climatic influences. A detailed discussion of the water-table is presented in Section 4.0.

Recharge to the unconfined flow system occurs primarily from infiltration of precipitation and irrigation, seepage from lakes and streams, and inflows from subcropping confined Denver Formation zones. Leakage from manmade structures, such as the manufacturing complexes, chemical and sanitary sewer systems, basins, canals, and buried pipelines, contribute a lesser amount.

2.2.2 Confined Flow System

Confining conditions exist within the Denver Formation where relatively impermeable strata separate the unconfined flow system from deeper permeable zones. Groundwater in the Denver Formation that is under pressure greater than atmospheric is part of the confined flow system.

Groundwater flow in the Denver Formation occurs primarily in permeable sandstone and siltstone. The discontinuous and variable nature of Denver Formation permeable strata results in complex hydraulic flow patterns and a high degree of variability in hydraulic conductivity

(Ebasco, 1989a). The previous definition of six to eleven separate confined water-bearing zones is probably not appropriate for extensive areas due to the discontinuous nature of the Denver Formation and observed conditions. Flows are most likely convoluted through laterally variable media. Groundwater also may flow along isolated local fracture systems in shale and claystone, which otherwise form confining layers.

Hydraulic head in the confined flow system decreases with increasing depth in most locations at RMA. Groundwater flow is the result of greater precipitation and enhanced recharge along streams in upland areas of the Denver Basin (e.g., Castle Rock area), combined with discharge to low points in the Denver Basin (e.g., South Platte River) and pumping. Discharge from the confined flow system occurs by lateral flow to the unconfined flow system where permeable zones of the confined flow system subcrop.

3.0 PROGRAM STRATEGY

1992 GMP activities were designed to meet the objectives discussed in Section 1.3. Three monitoring events were performed during the 1992 GMP: Winter 1991/92, Spring and Summer 1992. This section summarizes and compares the 1992 water-level monitoring and groundwater sampling networks to previous networks. Brief descriptions of water-level measurement, groundwater sampling collection, and the quality assurance/quality control (QA/QC) program objectives are also included.

3.1 WATER-LEVEL MONITORING

Water-level data are important in evaluating groundwater and contaminant movement. As part of the GMP, water-levels in approximately 1,200 monitoring wells are measured prior to each groundwater sampling event to provide seasonal information on potentiometric surfaces in the unconfined and confined flow systems. The water-level monitoring network was designed to evaluate data for both regional and local (project area) groundwater flow conditions.

3.1.1 1992 GMP Network Design

The 1992 GMP water-level monitoring network was designed to provide the most efficient areal coverage throughout RMA and offpost areas to evaluate the groundwater surface for both the unconfined and confined flow systems. The network was developed to maximize both areal and vertical coverage. Wells in clusters were preferentially selected to provide information on the vertical interaction between aquifer flow systems and variable depths within the same aquifer. These wells were included in the 1992 GMP water-level monitoring network to provide continuity to the water-level database and allow comparison with historical trends.

Selection criteria for wells included in the water-level monitoring network were similar for both the unconfined and confined flow systems. The current condition of the well and historical water-level data were reviewed and the areal distribution of wells was evaluated. Wells that were destroyed or abandoned and wells with obstructions were deleted from the network. Some historically dry wells were retained in the network to monitor potential water-table changes that could occur in response to IRA activities or seasonal fluctuations.

A list of water-level measurements recorded during the 1992 water monitoring year is

included in Appendix A (on diskette). The Winter 1991/92 GMP water-level monitoring networks for the unconfined and confined flow systems are shown on Plate 1 and Figure 3.1, respectively.

3.1.2 Comparison With Previous Networks

Although the GMP water-level monitoring network is designed to consistently use the same wells to ensure that quarterly data are comparable, the network changes slightly from year to year to include newly installed wells and to delete wells that have been abandoned or destroyed. The core wells that constituted the water-level monitoring network were initially selected from the Spring 1987 monitoring period from RI/FS Tasks 25 (NBCS and NWBCS monitoring networks) and 44 (regional monitoring network, including the ISP monitoring network).

The network has consistently grown since the inception of the CMP in 1988. The 1992 GMP water-level monitoring network, as defined in the D0 0006 Technical Plan, included 1,209 onpost and offpost wells. All of the wells from the 1991 CMP network were included in the GMP network with the exception of thirteen wells that were inaccessible for water-level measurements. No newly installed wells were added to the 1992 GMP water-level monitoring network.

3.1.3 Procedures

Standard field procedures have been established to achieve consistency and reliability in water-level measurements. These procedures are described in detail in the Rocky Mountain Arsenal Continuous Monitoring Program Ground Water Procedures (Stollar et al., 1990a).

Water-level measurements are collected within a short time frame to minimize time-related effects. An electronic conductivity probe is used to measure the depth to water from the top of the inner well casing (TOC). The water-level elevation at each well is calculated using the field measurements and previously surveyed TOC elevations.

3.1.4 Quality Assurance and Quality Control

QA/QC for water-level measurements occurs through field observations and data reviews. Field documentation procedures are detailed in the PMRMA Chemical Quality

Assurance Plan (CQAP) (PMRMA, 1989).

Site conditions are recorded, during water-level measurements, that could account for a discrepancy between current and previous measurements, such as subsidence features, broken casings, and downhole obstructions. The height of the well casing from ground level to the TOC, the depth to water, and the total depth of dry wells are compared to the previous measurements for each well. If unexplained discrepancies exist, field rechecks are performed to verify the measurement in question. The field personnel also check that the well is flagged and the well number is clearly labeled. At the end of each day, water-levels, depths of dry wells and TOC are compared to previous measurements for each well. If discrepancies are observed, a second measurement is performed for verification. Approximately one time per year, the field crew sounds total well depth to verify the integrity of the well.

3.2 GROUNDWATER SAMPLING

Groundwater samples are collected and analyzed for the target analytes listed in Table 1.2 to assess current contaminant distribution, changes in contamination patterns, and rates of contaminant migration. Water-quality monitoring is conducted to address regional and site-specific contaminant distribution.

3.2.1 1992 GMP Network Design

Water-quality sampling for the 1992 GMP was limited to the Basin F IRA area (Sections 23 and 26) to monitor the effects of remedial efforts. The network was designed using the CMP Basin F IRA area monitoring network (Stollar et al., 1990b) as a starting point and then modifying that network. The entire Basin F IRA network was sampled during Winter 1992 and a subset of this network was sampled during the Spring and Summer quarters. Table 3.1 summarizes 1992 groundwater sampling activities. The 1992 GMP water-quality sampling network is presented in Table 3.2.

A total of sixty-one wells (thirty-eight unconfined flow system and twenty-three confined flow system) comprising the annual Basin F network were originally scheduled to be sampled during the Winter 1992 sampling round. The flow system designations for thirteen confined flow system wells sampled during the Winter sampling event changed, after incorporation of the groundwater data evaluation flow system changes. As shown on Table 3.2, eight confined

flow system designations changed to unconfined and five confined flow system designations were identified as unknown or questionable. Analytical data for wells with unknown flow designation were not used for interpretation purposes in this report. In addition, five groundwater samples were not collected from four wells (26162, 26164, 26165, 26167) because of extremely slow recharge. Wells 26146 and 23180 had very slow recharge rates and, therefore, only partial analytical suites were collected. Table 3.2 lists the 57 wells that were sampled during Winter 1992 (42 unconfined flow system and 15 confined flow system wells). Well locations for the unconfined and confined flow system water-quality network are shown on Figures 3.2 and 3.3, respectively.

The Basin F IRA Technical Plan (Stollar et al., 1990b) originally identified eighteen unconfined flow system wells for the quarterly Basin F IRA sampling network. Table 3.2 lists the eighteen wells that were sampled during the Spring sampling event.

A total of twenty-nine unconfined flow system wells were sampled during the Summer sampling round. Eighteen of these wells were included in the original quarterly Basin F IRA sampling network outlined in the Basin F IRA Technical Plan (Stollar et al., 1990b). Six additional wells were added at the request of the State of Colorado, as well as three additional wells specified by PMRMA. Table 3.2 lists the twenty-nine wells sampled during the Summer sampling round.

Water-quality data collected by MKE were obtained to evaluate contaminant distribution in unconfined flow system wells in the vicinity of the NBCS and NWBCS. Both Army-certified and U.S.Environmental Protection Agency (USEPA) methods (USEPA, 1988) were performed for these samples during the 1992 water monitoring year. The results are presented on the histograms, but were not plotted or compared to 1992 GMP data shown on the contaminant distribution maps. Figure 3.4 illustrates the locations of the wells with available 1992 data that were evaluated for the boundary system contaminant distribution analysis.

3.2.2 Comparison With Previous Networks

The GMP water-quality sampling network has evolved from previous regional and project-specific RMA monitoring networks as described in Section 1.3 and has changed over time. From 1988 to September 1991, the Army implemented the groundwater element of the CMP. The objective of the CMP was to assess the occurrence and migration of contaminants within the hydrogeologic environment at RMA and support the feasibility study (FS) and the

ROD process.

When the CMP concluded in 1990, the Army had established a historical perspective of the movement and distribution of contaminants within the groundwater underlying areas onpost and offpost at RMA. Regionally contaminant distribution and migration appeared to remain fairly static, as did hydrologic conditions. The Army concluded, as a result of performing the CMP, that the size of the groundwater quality monitoring network could be reduced. Before the 1990 CMP field program, an addendum to the CMP Task Plan was submitted to the Organizations and State (OAS). This addendum (Stollar et al., 1990b) described a groundwater monitoring program that reduced the frequency of the regional groundwater quality sampling network from an annual frequency to a semiannual frequency (approximately 620 wells) and reduced the semiannual sampling network from approximately 400 wells, to a benchmark network of approximately 200 wells that would be sampled every other year. The quarterly regional water-level network was retained as part of the program because the Army believed that an accurate picture of hydrologic conditions was required to assess the effectiveness of the boundary systems and to evaluate changes that may be a result of IRA activities.

During the 1991 CMP, the benchmark network was sampled during the Winter 1990/91 quarter and the Basin F quarterly network was sampled during Spring and Fall 1991. Revisions to the Basin F sampling network were presented in the Draft Final Basin F IRA Ground and Surface-Water Monitoring Program, an appendix to the Basin F IRA Operations and Maintenance Manual (Stollar et al., 1990b). OAS reviewed and commented on this program, which consisted of a large Basin F sampling network of 60 wells to be sampled annually and approximately 20 wells to be sampled quarterly during the remainder of the monitoring year.

During the transition from the CMP to the GMP, programmatic changes were necessary to support the design and implementation of future groundwater monitoring programs. Because of time constraints, the Army prepared a one-year interim program, the 1992 GMP, that provided for the collection of regional water-level data and groundwater samples from the Basin F IRA area for the 1992 GMP. The 1992 groundwater monitoring element of the GMP was not meant to replace the CMP, but rather be a mechanism to implement the revised Basin F sampling program.

3.2.3 Procedures

The groundwater sampling procedures followed during the GMP are consistent with the

methods outlined in the CQAP and its Supplements (PMRMA, 1989). The procedures used for groundwater sampling are described in detail in the Rocky Mountain Arsenal Continuous Monitoring Program Ground Water Procedures (Stollar et al., 1990a) and are briefly described here:

- Water level is measured.
- The well is purged by removing five casing volumes of water, if possible.
- Groundwater samples are collected in containers specified by PMRMA.
- Groundwater samples are sent to PMRMA-designated laboratories for chemical analyses.

3.2.4 Chemical Analysis

The groundwater samples collected during the 1992 water monitoring year were analyzed using the PMRMA-certified methods for the analytes listed in Table 3.3. Most analyses were performed at DataChem Laboratories (Salt Lake City, Utah) with specific organic parameters performed at Environmental Science and Engineering Laboratories (Denver, Colorado, and Gainsville, Florida). The certified reporting limit (CRL) for each analyte can vary between laboratories, as shown on Table 3.3. Concentrations of all analytes detected by non-gas chromatography/mass spectrometry (GC/MS) methods are presented by site identification (ID) number in Appendix B (on diskette). Non-GC/MS methods include colorimetric, high performance liquid chromatography (HPLC), ion chromatography (IONCHROM), atomic absorption spectrometry (AA), inductively coupled argon plasma screen (ICP), and gas chromatography coupled with a conductivity detector (GC/CON), electron capture detector (GC/ECD), flame ionization detector (GC/FID), flame photometric detector (GC/FPD), nitrogen phosphorus detector (GC/NPD), and photoionization detector (GC/PID).

GC/MS analyses were performed at Datachem laboratory for the purpose of identifying nontarget compounds and confirming GC analysis if the concentrations were within the GC/MS range. The CRLs for GMP target analytes for the GC/MS method are listed in Table 3.4. Groundwater samples sent for GC/MS analysis were collected during Winter, Spring, and Summer sampling events (Table 3.1) from approximately 11 percent of the total investigative samples. Tentative ID of nontarget analytes was made, when possible, on the basis of spectral

analysis. When nontarget analytes were positively identified and consistently detected at elevated levels, they were reviewed more closely by PMRMA chemists for their significance. The results of GC/MS analyses are presented in Appendix C (on diskette).

3.2.5 Quality Assurance and Quality Control

The objectives of the QA program for the RMA GMP are as follows:

- Follow technically defensible and consistent sample collection and analysis procedures.
- Document that procedures used in the collection, preservation, and handling of samples are complete, traceable, and retrievable.
- Assess Data Quality Indicators for data usability.
- Perform laboratory analyses of all samples, including those collected for QC, according to documented certified procedures.

Field, analytical, and project procedures established by PMRMA provide consistency of methods for legally defensible data. Standard field procedures include well purging, monitoring field parameters (temperature, pH, electrical conductivity, alkalinity, and dissolved oxygen), sampling, and equipment decontamination. Documentation of sampling procedures consist of maintaining field logbooks, and separate field data sheets for each well, and completing chain-of-custody (COC) forms for each sample shipment. The COC accompanies the sample from field collection to the analytical laboratory and final hard copy reporting in data packages.

Analytical standard procedures involve verifying sample receipt, requested analyses, and preservation; proper storage; tracking sample status; performing sample preparation and analysis according to the specified PMRMA methods; validating sample results; generating electronic and hardcopy data transfer packages; and disposing of sample remains and extracts.

Project standard operating procedures encompass the documentation of project activities; storage of documentation (electronic and hardcopy); incorporation of quality into activities and reports, and archive and transfer of all PMRMA-generated materials to the Project Management Office.

4.0 1992 GMP DATA RESULTS

This section summarizes water-level monitoring and groundwater water-quality data results for the 1992 GMP. All data presented in this report are provided on diskette in Appendixes A through D. A summary of the 1992 GMP field data collection effort is provided below.

Season	Number of Water-Level Measurements	Measurement Dates	Proposed Water Quality Wells	Number of Wells Sampled	Water-Quality Sampling Dates
Winter 1991/92	1,188	12/3/91 to 1/9/92	61	57	1/9/92 to 1/29/92
Spring 1992	1,266	3/3/92 to 3/24/92	18	18	3/14/92 to 4/2/92
Summer 1992	1,226	6/2/92 to 6/19/92	29	29	6/15/92 to 6/19/92

4.1 GROUNDWATER DATA EVALUATION STUDY

A Groundwater Data Evaluation (HLA, 1994) of GMP confined flow system well data was recently completed that identified flawed and inconsistent data in the RMAED. An evaluation of the confined flow system well data was necessary to provide accurate information to assess the vertical extent of groundwater contamination at RMA. The final flow system designation classifications from the data evaluation have been incorporated into the 1992 GMP database to present the most updated and complete technical information for this report.

As described in Section 1.5, specific objectives and criteria provided the basis for evaluating over 800 confined flow system wells. These included:

- o Evaluate confined flow system well construction data with respect to well construction integrity, suitability for groundwater sampling and hydrologic data collection.
- o Evaluate confined flow system water-level data for confined flow system wells to identify data that appear to be inconsistent with historical observations.

- o Evaluate confined flow system water-quality data to identify whether any data appear consistent with historical observations or whether the contaminant concentrations are low enough not to be of concern.

Well construction, water-level, and water-quality data were evaluated to assign a flow system designation for each of the wells screened in the Denver Formation. In many cases, it was determined that the flow system designation historically used by the GMP was contrary to the information reviewed and the flow system was changed to unconfined. In other cases, a determination of flow system could not be made with available data, and the well was placed in an unknown flow system category. Both water-level and water-quality data for unknown flow system wells are not considered representative of either the confined or unconfined flow system and the data were not used for interpretation in this report.

Table 4.1 lists the flow system classification changes for the 1992 GMP monitoring wells. Data for wells that have a question mark after the flow system are considered questionable because of conflicting data. Additional information is needed to make a definitive determination. However, for interpretation purposes, water-level and water-quality data from these wells will be used until additional research indicates otherwise. For the 1992 GMP, the following number of wells were reclassified:

- o 125 confined Denver wells changed to unconfined
- o 45 confined Denver wells changed to unknown
- o 1 unconfined well changed to unknown
- o 5 wells without designations (no designation) changed to unconfined
- o 6 no designation wells changed to confined
- o 1 no designation well changed to unknown

4.2 WATER-LEVEL MONITORING DATA

Water-level measurements obtained during three monitoring periods for the 1992 GMP were integrated with well coordinate and elevation data to produce water-table maps of the unconfined flow system. Detailed configurations of the water-table surface in the northern IRA areas are shown in Section 5.0 for the three monitoring periods in 1992. The northern IRA

area includes the NBCS, NWBCS, Basin F IRA area, Basin A-Neck (BANS), and ICS.

In addition to 1992 GMP data, concurrent water-level measurements collected by the Technical Operations Division (TOD) of the Army and the U.S Geological Survey (USGS) were used to supplement the database and aid in evaluating the water-table surface in the boundary system areas. When these data were used, they were selected to correspond to the date of the closest 1992 GMP monitoring event for each area. To ensure the data represent a single set of hydrologic conditions, data collected more than two weeks before or two weeks after the 1992 GMP monitoring event were not incorporated. The TOD and USGS data were collected from a dense well network that provides frequent water-level information in support of boundary system operations. The number of wells included in the water-level networks for the 1988 through 1992 water monitoring years are summarized in Table 4.2.

Integration of the reclassified confined flow system designations from the 1994 groundwater data evaluation study changed 125 confined wells to unconfined and 45 confined wells to an unknown (and, thus not usable) flow system in the 1992 GMP. These changes resulted in a total of 182 confined wells for the Winter 1992 water-level database and created insufficient areal coverage to produce potentiometric surface maps of the previously defined six uppermost confined Denver Formation water-bearing zones. The discontinuous and variable nature of Denver Formation permeable strata results in complex hydraulic flow patterns and a high degree of variability in hydraulic conductivity (Ebasco, 1989b) that also creates difficulty in contouring potentiometric surfaces from one area to another. The previous definition of six to eleven separate confined zones in the Denver Formation may not be appropriate for extensive areas due to the discontinuous nature of the Denver Formation and observed conditions. While the system is undoubtably complex, the flows are probably convoluted through laterally variable media. For the 1992 GMP data interpretation and presentation, the data is grouped into one unconfined and one confined flow system zone.

4.2.1 Unconfined Flow System

Water-level data from wells screened in the alluvium and upper unconfined portions of the Denver Formation were used to construct unconfined flow system water-table elevation maps for the three monitoring events in 1992. Water-level maps were constructed by contouring the data points using Quicksurf contouring software and triangulation methods. The computer-generated maps were carefully examined for anomalies and geologic discrepancies. Isolated

data points that appeared anomalous with the surrounding data were reviewed and omitted if the water-levels exhibited significant differences with historical water-level data. Field comments listed in the RMAED regarding the condition of the well or other problems (such as siltation) were also reviewed and recorded as additional backup for the data point deletion. Water-levels for wells screened in the alluvium were only used for the alluvial/unconfined Denver Formation well pair sites. Table 4.3 lists the water-level outlier site ID's that were omitted on each contour map.

The water-table maps (Figures 4.1 through 4.3) show areas where the alluvium is interpreted to be unsaturated. Areas of unsaturated alluvium also represent bedrock highs. In areas of unsaturated alluvium, groundwater flow in the unconfined flow system is within the upper portion of the Denver Formation. Areas of unsaturated alluvium were identified using 3-dimensions in the Geographic Information System (GIS) by overlaying the Winter 1992 contoured head map on the bedrock surface map. Areas of unsaturated alluvium exist where the bedrock surface is higher than the hydraulic head elevation. The unsaturated alluvial areas may be modified during the ongoing GMP to reflect additional water-level data obtained from newly installed wells that were not incorporated into the 1992 RMAED. The bedrock surface map used to assess areas of unsaturated alluvium was based on a composite map generated by HLA and entered into the Army's GIS.

The configuration of the water-table surface during the Winter, Spring and Summer quarters is illustrated in Figures 4.1 through 4.3. The regional slope of the water-table is from southeast to northwest with elevations ranging from 5303 feet (ft) above mean sea level (MSL) in the extreme southeast corner of RMA to 5090 MSL in the northwest portion near the NWBCS. Groundwater flow generally follows the slope of the bedrock surface and discharges to the South Platte River approximately two miles northwest of RMA.

The water-table gradient during the Winter quarter ranged from approximately 0.001 (ft/ft) to 0.08. In many areas, local changes in gradient correspond with changes in the configuration of the bedrock surface. In areas of relatively thick and uniform alluvium, such as occurs in the eastern and northwestern portions of RMA, the water-table is relatively flat with a gradient of approximately 0.004. The central portion of RMA is characterized by thin and uneven alluvium overlying an irregular bedrock surface. This area exhibits an irregular water-table surface and steep hydraulic gradients of approximately 0.02 to 0.03.

A predominant anomaly in the water-table surface, also reported in previous groundwater

studies at RMA, is a groundwater mound located in the South Plants area. This mound coincides to a mound in the bedrock surface (HLA, 1992b) that subcrops near the center of the South Plants area where alluvium is thin to absent. Groundwater flow in this area occurs within the unconfined Denver Formation and the mounding effect has also been attributed to the lower hydraulic conductivity of the bedrock (Stollar et al., 1991).

Groundwater flow along the north and northwest boundaries at RMA has been modified by systems operation of the NBCS and NWBCS. The bentonite slurry wall, interception, withdrawal, and recharge of groundwater has caused deviations from regional patterns. Localized effects were also seen in the area of the ICS in Section 33. A more detailed discussion of these effects is presented in Section 5.0.

The configuration and level of the regional water-table surface remained relatively constant from Winter through Spring 1992. Water-level fluctuations were generally less than two feet over the south, central, and eastern portions of RMA. The major fluctuations occurred in downgradient wells adjacent to the eastern end of the NBCS. In the NWBCS area, water-levels fluctuated quarterly in wells downgradient of the barrier wall.

In general, water-levels were lowest during the Summer monitoring period. Southwest of the ICS in Section 33, water-levels were up to eight feet lower in the Summer quarter as compared to the Winter and Spring monitoring data. Water-levels were also one to three feet lower during the Summer quarter near the center of the groundwater mound in the South Plants area in Section 1.

4.2.2 Influences on Data Interpretation

The 1992 GMP water-level data reflects changes that were made in reevaluating the confined Denver flow system groundwater data. Integration of the groundwater data evaluation flow system changes created a larger unconfined flow system data set that incorporated 125 new wells into the unconfined GMP water-level network. However, no newly installed monitoring wells for the 1992 GMP were incorporated into the RMAED. The use of supplemental TOD and USGS data also provided a larger set of water-level data than was utilized in previous years. A few wells measured during the 1991 CMP were destroyed or abandoned during the 1992 GMP.

4.2.3 Aquifer Interactions

Potentiometric data from both confined and unconfined flow system wells were used to assess aquifer interaction between hydrologic zones. Vertical gradients were calculated from well cluster sites for unconfined and confined well pairs as well as alluvial and unconfined Denver Formation well pairs to provide a more complete regional review of potential vertical movement in the groundwater system at RMA.

4.2.3.1 Vertical Gradient Analysis

Vertical gradients were calculated as the difference in hydraulic head between the unconfined and confined flow system (or alluvial and unconfined Denver) divided by the distance (length) between the screen midpoints (dh/dl). The annual and quarterly gradient direction was determined by counting the total number of upward and downward vertical gradients measured during that time. If upward vertical gradients were predominantly measured, or the magnitude of a quarterly upward gradient was significantly higher than the downward measurement, then the overall vertical gradient was judged to be upward. Vertical gradients were calculated for each water-level measurement and an average quarterly vertical gradient was determined by averaging the individual vertical gradients for each quarter. An approximate average annual vertical gradient was calculated as the average of the quarterly measurements.

The unconfined flow system and stratigraphically adjacent confined water-bearing zone were monitored by twenty-seven well clusters. Table 4.4 summarizes all vertical gradient measurements and individual gradient direction for each of these well pairs. The locations and hydraulic gradient directions at the well cluster sites for each quarter are shown on Figure 4.4. In general, there is a downward vertical gradient between the unconfined/confined flow systems, the magnitude of which lessens toward subcrop areas. Downward gradients existed in twenty-five of the twenty-seven well cluster sites shown on Table 4.4 and ranged from 0.002 to 0.53. Upward vertical gradient values ranged from 0.003 to 0.14.

Vertical gradients were also calculated for forty-five well clusters screened in the unconfined alluvial and unconfined Denver flow systems. Table 4.5 summarizes these well clusters and associated vertical gradient calculations. The locations of these well clusters and measured quarterly vertical gradient direction are graphically illustrated on Figure 4.4. The

predominant hydraulic vertical gradient direction is downward and existed in thirty well clusters. Downward gradients ranged from 0.001 to 0.56. Upward vertical gradients were shown in fifteen well clusters during at least one quarter and ranged from 0.002 to 0.23. The downward vertical gradient values between unconfined/confined flow system well clusters are greater in magnitude than downward gradients between unconfined alluvium/Denver Formation flow system well clusters. This is primarily due to a greater difference in head values between the two stratigraphically adjacent flow system wells.

There is a potential for downward movement of groundwater from the unconfined flow system to the confined flow system; however, actual movement also depends on the vertical hydraulic conductivity between units. A small vertical gradient difference between adjacent wells indicates that the wells may be within the same flow system, the confining unit is thin, or the confining unit has relatively large vertical conductivity. Small downward gradients are also associated with claystone units that are fractured and/or weathered. The largest downward or upward vertical gradients correspond to clusters where a confining layer was thickest or most competent. The existence of vertical gradients does not necessarily imply that significant groundwater exchange occurs between the unconfined and confined flow systems. Instead, aquitards inhibit vertical groundwater flow. The magnitude and direction of the vertical gradients appear to reflect the degree of confinement between water-bearing zones.

The potential for upward movement from the confined flow system to the unconfined flow system exists in areas where the potentiometric surface of the confined flow system is higher than the water table in the unconfined flow system. A greater number and magnitude of upward vertical gradients occur between wells located within the unconfined alluvial/ Denver Formation well clusters than unconfined/confined flow system well clusters. This finding indicates that although both wells in an unconfined well cluster have been assigned an unconfined flow system classification, lithologic stratification or other local heterogeneities, such as discontinuous clay and sand lenses, exist that may cause localized gradient variations.

4.3 BASIN F ANALYTICAL DATA RESULTS

Groundwater sampling during the 1992 GMP was limited to the Basin F IRA area. Water monitoring activities were performed in this area to evaluate the effects of the Basin F IRA on groundwater flow and contaminant migration. The following subsections summarize 1992 GMP analytical data results. Quality Assurance/Quality Control (QA/QC) data results are presented

first, to define the quality and useability of the 1992 water-quality data and discuss rejected data. Data used for interpretation purposes are summarized following the QA/QC analysis.

4.3.1 Quality Assurance/Quality Control

To control and measure quality for the 1992 GMP analytical data the 1989 CQAP guidelines were used. In addition, Draft Version 1.0 of the September 1993 CQAP was consulted to provide a more universal method for obtaining an evolving total quality data assessment program. The following criteria were used from the Version 1.0 edition of the CQAP:

- o Application of Type I, II, and III criteria
- o Application of Data Quality Indicators as measurement tools

4.3.1.1 Quality Assurance/Quality Control Data Results

Investigative and QA/QC results are compared to five quality parameters: Precision, Accuracy, Representativeness, Comparability, and Completeness (PARCC). There are varying degrees of these parameters, depending on what type of data is needed to meet the data quality objectives (DQOs) for the field program. The DQOs are a combination of the uncertainty associated with sample collection and analysis activities using the PARCC parameters as measurement tools. Table 4.6 contains the projected and actual PARCC parameters for the 1992 Annual Groundwater Monitoring Report. The GMP as a monitoring and continuing investigative program, uses DQO's similar to those for remedial investigations (USEPA, 1987). The USEPA DQO's were the standard used as a measurement tool to evaluate and qualify field and laboratory practices.

Precision calculations were based on duplicate and historical comparison analyses. Accuracy was observed for a limited data set during review of data packages. Representativeness was calculated on the basis of the use of good field practices, designated sampling procedures, and proper equipment. Completeness was calculated from the number of results collected versus the number of usable data points (those meeting PMRMA and DQO requirements). Comparability was based on static sampling and analytical procedures.

Field notebooks and audits are used to assess compliance with written field procedures

and collection data quality. Laboratory control charts for analytical methods, individual data packages, and audits are used to measure laboratory data quality. Trip, rinse, field, duplicate, and conformational samples compose the field QA/QC data. Method blanks, spikes, and conformational analyses comprise the laboratory QA/QC data. The compilation of QA/QC results and PARCC parameters are used to assess the total quality and final usability of sample results.

Based on the QA/QC review, data is placed into one of three categories: fully usable, usable with qualifications, and rejected. Rejected data, although not usable for the present field program, can be used to redefine future field activities through recommendations and changes to more efficient and effective planning and implementation.

Unconfirmed results (QC or investigative) are not usable for 1992 GMP data interpretation for methods where a second column confirmation is part of the written method. These results are flagged with a "U" in the RMAED.

Field Quality Control Blank Data

Field quality control blanks consist of field, rinse, and trip blank samples. The total number of QA/QC and percentages of blank samples collected during the 1992 GMP sampling events are summarized in Table 3.1 and shown below.

1992 GMP Monitoring Event	Number of Rinse Blank Samples	Number of Field Blank Samples	Number of Trip Blank Samples
Winter	2	2	3
Spring	1	1	1
Summer	1	1	1
Percentages	4%	4%	5%

Field and rinse blank data consisted of inorganic elements and compounds. Most of the constituents are water soluble and are present as ions (anions and cations). When compared to natural water, the field and rinse blank data contain the same constituents. These constituents characterize the dissolved solids content of water.

The objective for collecting anion and cation results is to check and compare sums of the two ion groups. An imbalance suggests additional constituents are present or an error has been made in the calculations or during field sampling operations.

Field QC samples are based on a treated water called ASTM Type II or deionized water. This water is tap water specifically treated to reduce some of the natural constituents. The process is not 100 percent effective and some residual is expected, as is seen in the results of the field and rinse blanks.

The major dissolved constituents normally present in natural water consist of (Peavy et al., 1985):

- o sodium
- o calcium
- o magnesium
- o sulfate
- o chloride
- o bicarbonate
- o iron
- o potassium
- o fluoride
- o nitrate

Analytical data from the field and rinse blanks are compared to the investigative samples collected on the same day. This process for assessing blanks allows for the greatest amount of consistency in applying blank results for representativeness and evaluating the effectiveness of field sample collection procedures.

Statistical analyses performed on the 1992 GMP QC data included the Dixon outlier test (CQAP, 1989) and the two standard deviation calculation to determine 95 percent confidence limits (CQAP, 1993). Both tests provide information concerning the amount of uncertainty associated with any one result or group of results. For the 1992 GMP, a 5 percent uncertainty is acceptable. Therefore, a statistically valid value represents a value within the 95 percent confidence limits and is usable for data interpretation. A statistically anomalous value represents a value that falls outside of the two standard deviation limit. More than 5 percent uncertainty is associated with a statistically anomalous result and is therefore, not usable for data interpretation.

Data that was determined to be unusable because it did not meet data quality objectives or quality parameter measurements were not flagged in the RMAED. The form of QC data

assessment that was performed included a condensed validation effort to assess data usability and is not intended to provide complete data validation with appropriate flag codes. The RMAED only includes codes placed by the laboratory and the laboratory support division (LSD) at RMA.

Field Blank Data. Field blanks are reagent-free media (traditionally deionized water or ASTM Type II water) transferred to sample collection bottles in the field, taken to sampling points, opened briefly at the site, and treated as an investigative sample through laboratory analysis. The data associated with these samples are flagged with an "F" in the QC code field. Results from field blanks assess the contamination associated with sample collection (including bottles), handling, and shipping. Field blanks for the 1992 GMP were analyzed for all the target analytes.

For the 1992 field program, field blank results were applied to all samples collected on the same day the field blank was taken. Field blank concentrations must be less than 5% of the investigative sample for the investigative sample result to be usable and valid (PRMA, Version 1, 1993). The field blank results were applied to both detections and non-detections or less than the CRL results. Table 4.7 summarizes field blank results, wells affected, and the calculated concentration that the investigative sample must be greater than in order for the data to be usable.

Trace metal inorganic constituents detected in the four field blank samples and the associated "greater than" concentration for the investigative sample are listed in Table 4.7. Investigative samples with less than the calculated values (unless they were less than the CRL) were not used for assessment of groundwater systems for the 1992 GMP. No source of the contaminant was identified. No semivolatile or pesticide detections were observed in any of the field blank samples collected during the 1992 GMP.

Nitrate is a common constituent of natural waters and appears in all of the field blanks, as well as the rinse blanks. This indicates a common source of contamination originating from the bottles, laboratory glassware, or some standard item used for all sample collection and analysis activities. However, since nitrate is a secondary constituent found in natural waters these results are useable with qualifications (as noted above) for 1992 GMP data presentation.

There is only one detection of sulfate, which is at an elevated level. The Winter field blank for site ID 26015 reported sulfate at 93,000 μg/l. This detection is statistically anomalous (the value falls outside the two standard deviation limit) and more than 5 percent uncertainty

is associated with this result. Therefore, this value was not used to determine usability of the sulfate data. The PMRMA LSD is currently investigating this result to identify evidence of dilution or transcription error.

Rinse Blank Data. Rinse blanks are reagent-free media (ASTM Type II or deionization) taken from newly decontaminated sampling equipment to assess the effectiveness of decontamination procedures. For the 1992 GMP, rinse blank results were applied to all investigative samples collected within the same day the rinse blank was collected. Rinse blank data is flagged with an "R" in the QC code field in the RMAED. Rinse blank samples are analyzed for the same set of target analytes, except for volatile organics.

The site ID where the rinse was performed is used as the rinse ID. The 5% rule, as described above, is relevant to the rinse blank data as applied to the investigative samples. Tables 4.8 through 4.10 summarize rinse blank artifact concentrations and the calculated concentration that the investigative sample must be greater than in order for the data to be usable and valid. Investigative sample concentrations that were not detected are acceptable for data presentation.

One rinse blank exhibited detections of aldrin and dieldrin (Winter 1992, Well 23221) at levels which impacted investigative sample results. This data package, and other suspect dieldrin data packages, were reviewed at the RMA Technical Information Center (RTIC). The following are a summary of the findings;

- o Detections of aldrin and dieldrin were confirmed by the second column analysis.
- o No matrix interference was observed.
- o Some sample chromatograms indicated a need to use GC/MS for analysis. Chromatograms were categorized as a "picket fence" or a Type III sample (Version 1.0, 1993 CQAP and 1989 CQAP Supplement) causing possible erroneous results.
- o Carryover from sample to sample was not observed. Laboratory method blanks were analyzed until there were not detections of the target analytes.

Using the 5% rule, five samples were listed as not usable for 1992 GMP data interpretation. These site ID's include; 23095, 23188, 23191, 23221, and 26129. A comparison of historical results to the 1992 results showed these five samples and five other

dieldrin analyses at a greater than 10-fold difference, or atypical of the groundwater system at RMA. Upon further review of the dieldrin data, other detections at low levels (but within the 10-fold criteria) appeared where, historically, there was no indication of dieldrin. Most of the dieldrin analytical data packages were not available on microfiche for review. Since potential usability problems cannot be confirmed, these results are considered valid until additional information can be obtained and reviewed.

Data for wells showing blank artifact contamination and documented flawed laboratory method analyses are found in the RMAED. After application of the DQOs for the 1992 GMP (Table 4.6) these are not included in plume maps or used in the interpretation of groundwater results. However, no additional flags were added to the data in the RMAED.

Trip Blank Data. Trip blanks are reagent-free water, typically designated as ASTM Type II or deionized water. Trip blanks are collected to evaluate any volatile compound contamination associated with the sample handling, shipping, and laboratory storage of samples sent for volatile analysis. The trip blank is not analyzed for any other target analytes since volatiles are the most likely compound grouping to penetrate sample containers.

Out of the five trip blanks analyzed, only chloroform was detected in two samples. Chloroform is considered a possible field and/or laboratory contaminant. As with all previous blank contamination, the 5% rule applies to all samples collected and in this case, analyzed with the trip blank since it may indicate laboratory contamination. Table 4.11 summarizes chloroform concentration detections in the trip blanks and the calculated concentration that the associated investigative samples must be greater than to be considered for incorporation into the 1992 GMP data assessment. Investigative chloroform detections less than the CRL are acceptable and are included in the 1992 data presentation. These results have not been impacted by blank artifact contamination.

Field Duplicate Evaluation

Field duplicates are samples split from the same aliquot of media collected to assess the reproducibility from field and laboratory activities. There were ten duplicate pairs collected during the 1992 GMP. A comparison was only possible for those pairs where a detection was observed in both samples. Duplicate sample pairs that showed a result less than the CRL or duplicate sample pairs with one less than the CRL value were not used to assess duplicate comparability. A value reported at less than the CRL is not an indication of a detected

compound, but a limitation of the analytical method and instrumentation. The actual value may be from zero to the detection limit and cannot be accurately defined for this assessment. Therefore, only duplicate pairs with results above the CRL were used.

Relative Percent Difference (RPD) calculations were performed to indicate the difference of the two samples relative to the average of the two samples. Table 4.12 summarizes RPD values for duplicate samples. As shown in Table 4.12, the average RPD for the entire duplicate data set was 12. RPDs within 20 are acceptable for organic analyses. Five RPDs out of 168 duplicate pairs were not statistically valid and were excluded from the average calculation. No additional flag codes were added to these data in the RMAED.

Gas Chromatography/Mass Spectrometry Data.

GC/MS analyses are performed to provide information on any detected, non-target compound and to confirm GC analyses if the sample is considered a Type III (highly contaminated), or the concentrations of the sample are within the GC/MS range. A Type III sample contains a significant amount of media and instrument interference that causes the potential for reporting false positive results.

Eleven GC/MS samples were collected for the 1992 GMP. Three samples indicated unknowns for volatiles and eight samples indicate unknowns for semivolatiles. DataChem was the laboratory performing the UM21 (volatile) and UM25 (semivolatile) analyses.

Confirmation of GC Results. Volatile analyses by GC were compared to GC/MS results for confirmational purposes. Table 4.13 presents a summary of GC/MS confirmation results. Only values seen by both analyses are shown Table 4.13. Semivolatile analyses by GC were compared to GC/MS results for confirmational purposes. Only those values seen by both analyses are presented. Although a value less than GC by GC/MS vaguely confirms a GC value below the GC/MS detection limit, these are considered indirect comparisons and not valid confirmations.

Two winter GC/MS samples contained detections of one component. Well 23237 and 26169 detected chloroform at 23,000 μg/l and 3.3 μg/l, respectively. Neither GC sample contained chloroform results. No comparison could be made.

Results from the GC/MS analyses confirm the presence and magnitude of GC results when both results are within the method's concentration range. Greater than results from the GC/MS method tentatively confirm magnitude while directly verifying the presence of the

compound. These confirmations relate to the verification procedure using GC/MS. The process is valid for the 1992 GMP data.

Tentatively Identified Compound Results. Compliance with the RMA QA program includes the review of GC/MS results for the presence of non-targeted analytes by the project's analytical and chemical specialists. Non-targets are considered "unknowns" until they are analyzed against a pure standard for positive ID. Compounds from naturally occurring substances and processes, field and/or laboratory contamination, or any degradation compounds associated with the list of targeted analytes are the probable "unknown" origins.

Criteria used to determine the presence of an "unknown" compound are listed in the RMA CQAP (PMRMA, 1989). These criteria are as follows:

- o The area of the unknown peak must be greater than 10% of the internal standard area peak.
- o For a tentative ID, the unknown spectral masses and the library spectral masses must be comparable. At least 80% of the masses should match intensity and proportions to the library spectra.
- o Matches of less than 80% are identified as unknowns or UNKs in the RMA database. UNK numbers less than 500 are associated with the volatiles analysis. Those equal to or greater than 500 are unknowns associated with the semivolatile analysis.
- o All unknown and tentatively identified compounds are flagged with an "S" in the flag code field.
- o Tentative ID and unknown concentrations are estimated. Standards must be used to properly identify and quantify compound concentrations.

Search and comparison of spectra entails the use of a software program where the unknown spectra is matched to a library of up to 72,000 known spectra (compounds). Since UNK numbers only represent a relationship between the unknown compound's retention time and the retention time of the internal standard, further investigation was performed to provide a more in-depth analysis of the GC/MS unknowns. An UNK number does not provide a correlation between the number and the actual ID of a compound. Any one compound could have many UNK numbers. Subsequently, the same compound does not always have the same calculated UNK number. These numbers can vary between analyses. For the 1992 GMP, data

interpretation and final review of the unknowns included frequency of occurrence in any one well or group of wells and chemical group type (e.g. straight-chain, halogenated, and nitrogen-containing hydrocarbons) obtained from the individual data packages. Assessment of unknowns included the following assumptions:

- o Unknowns with the same numbers represented the same or similar compounds and could be grouped together for a frequency evaluation.
- o Any unknown detection of 100 parts per billion (ppb) was arbitrarily set as a limit. More evaluation of the data was necessary to determine if the unknown was significant.
- o A frequency of three unknown numbers was arbitrarily set to identify potential recurring detections of the same or similar compounds.

Table 4.14 lists the frequency, chemical grouping, and maximum concentration detected of each tentatively identified compound and each unknown identified for the 1992 GMP. Table 4.15 lists any one occurrence greater than 100 ppb. Criteria for listing the unknown numbers were: Table 4.14, three or more occurrences and Table 4.15, greater than 100 ppb for any one occurrence.

Rejected Data

Data generated under the PMRMA certification program are reviewed through the control charting of laboratory spikes. These control charts pass initial inspection by the laboratory QA officer. A narrative is included to alert PMRMA of any situations that may have or were known to affect investigative sample results. Once the control charts are reviewed and accepted by PMRMA chemistry personnel, the electronic data is considered usable by project personnel. Data that does not meet the strict PMRMA QA requirements are placed in the rejected database. The PMRMA LSD has the ultimate decision on the acceptance or rejection of data. Data may be rejected for whole methods and by individual analytes. Table 4.16 lists the data by method that did not meet PMRMA QA requirements. The following are typical situations for the rejection of data:

- o Analysis holding time was exceeded
- o Spike recoveries were unacceptable
- o Spike recoveries were outside of 95% confidence levels
- o Spike recovery trends moving low or high

- o High blank results
- o Extraction holding time was exceeded
- o Instrument conditions changed during analysis
- o No certification available before analysis was performed

Rejected data is not used for interpreting analytical results, but may be used to revise future field programs.

4.3.1.2 Laboratory Analysis Influences on Data Interpretation

Data package reviews provide perspective on matrix and equipment interferences, analyst interpretation, and other outside influences whose information is not part of the RMA database. Chemist's notes and instrument print-outs are the basis for a detection being reported as valid and meeting method quality requirements. Data packages are on microfilm at the RTIC. Many of the data packages needed to review unknown, greater than, and historically inconsistent data were not available for incorporation into this 1992 Annual Groundwater Monitoring Report. The laboratory lot numbers and the corresponding site ID's for these missing data packages are listed in Table 4.17.

Eight analyses for fluoride reported concentrations as "greater than" values in the RMAED. Greater than values occur when the analytical laboratory is unable to dilute a sample before the holding time expires. Only one data package for these fluoride analyses was available for review on microfilm. The available data package sample chromatogram showed large spectral peaks that indicated potential high chloride concentration interference. Datachem laboratory personnel were contacted and related that these data should not be used if data packages were unavailable and possible chloride interference is believed to exist. The data for these samples will be found in the RMAED but were not plotted on the contaminant plume maps or summarized in the detection tables. The following site ID's for the rejected fluoride analyses include; 23188, 23191, 23239, 23241, 26157, 26166, 26168, 26169.

Fluoride results for method TU02, performed during the Summer 1992 sampling event only, were reviewed in the pre-QC electronic file in the RMAED. These results have not been evaluated for use by PMRMA LSD and were not used to assess the usability of fluoride results by method TT09 (used for the 1992 GMP) during that same period. The data for both methods were compared, and in every case the TT09 method result was higher than TU02 method result. Some TT09 results were 20 times higher than TU02 results. Method TU02 eliminates

chloride interferences and is more representative of fluoride concentrations at RMA.

Data packages for thirteen dieldrin analyses were not available for review on microfilm. Sample chromatogram reviews of available dieldrin analyses for the Winter 1992 sampling round were categorized as Type III samples and indicated a need to use GC/MS for confirmation analysis. Confirmational analyses by GC/MS is an option laboratories may use to substantiate the presence or absence of a contaminant (PMRMA, 1989). Without this confirmation, analytical results have the potential of being unrepresentative of the groundwater chemistry. Laboratories for the 1992 GMP did not perform these confirmational analyses.

Most of the samples collected showed dieldrin detections above that historically reported for that location. In addition, dieldrin detections in rinse blanks indicates that cross-contamination may have occurred in many samples. At least ten dieldrin analyses and, possibly, many of the other pesticide analyses performed during the 1992 GMP may not be representative of the groundwater chemistry in the Basin F area.

4.3.1.3 <u>Quality Assurance/Quality Control Conclusions</u>

The data quality objectives for the 1992 GMP include the comparison between projected and actual quality measurements. The assessment of quality includes the compilation of results from field and laboratory quality samples from rinse, field, and trip blanks; duplicate sample data; and GC/MS unknowns and confirmations. This data set was used to assess the effects of field and laboratory activities on the usability of the 1992 GMP data.

To summarize the field QC samples, the following is observed:

- o Field blank data contained detections of three metals: arsenic, cadmium, and zinc. Investigative samples collected the same day were flagged for their detections of these metals. The 5% rule was applied and eight samples were affected.

- o Field blank data contained detections of nitrate. All nitrate results are usable with qualifications because nitrate is a secondary constituent found in natural waters.

- o Field blank data contained one sulfate result. It is not statistically valid and will not be applied to any of the investigative data. All results within the RMA database are acceptable for use.

- o Field blank data contained various common ionic species of inorganics. These species are typical in ASTM Type II and deionized water and groundwater systems. Data associated with these inorganics are usable.

- o Rinse blank data contained chloroform, dieldrin, and aldrin. Chloroform did not affect any usable investigative sample results. Dieldrin and aldrin contamination affected five samples. Historical comparisons affected five other samples. These results are not usable for the 1992 GMP. Decontamination procedures have been subsequently reviewed and were revised for the 1993 GMP field program.

- o Trip blank data contained chloroform. One investigative sample was affected and was not usable.

- o Duplicate data correlated and were comparable. The average RPD for the entire duplicate data set was 12. Although no specific guidelines are available, RPDs within 20 show good reproducibility for organic analyses. Five RPDs out of 168 duplicate pairs were not statistically valid and were excluded from the average calculation.

- o GC and GC/MS data were comparable. Where both analyses detected the same compound, the GC/MS analysis verified the GC results in all cases.

- o GC/MS unknowns were reviewed and classified into chemical groupings. The cyclic hydrocarbon group was the most common designation. No other chemical attachment such as halogens were present. The conclusion is that GC/MS unknowns and their relative concentrations are typical and do not need further investigation.

Data quality objectives were met for the 1992 GMP for precision, accuracy, representativeness, comparability, and completeness for all data except Winter 1992 dieldrin and fluoride analyses. Missing data packages for suspect dieldrin and fluoride results could not be verified and thus, do not meet the PARCC parameters. In addition, laboratory protocol was not strictly followed for confirmation of Type III dieldrin GC analyses.

4.3.2 Groundwater Analytical Data

Analytical data for 1992 GMP target analytes are summarized in Tables 4.18, 4.19, and 4.20 for Winter, Spring, and Summer, respectively. Table 4.21 summarizes the analytical data for the unconfined and confined flow systems. NDMA, while not a target analyte, was included on this table because of the current concern regarding the lack of NDMA adsorption on the carbon treatment system at the NBCS.

Ninety-three percent (126) of the investigative and QA/QC groundwater samples collected during the 1992 water monitoring year were sent to DataChem laboratory in Salt Lake City, Utah, for analysis. DataChem performed the analyses for the complete GMP analytical suite for all except twelve samples, for which ESE-Gainesville performed selected organic acid

analyses (thiodiglycol, isopropyl methylphosphonic acid, methylphosphonic acid, and fluoroacetic acid). ESE-Denver performed two volatile organic compound sample analyses for DBCP and methylisobutyl ketone during the Winter 1992 sampling round.

4.3.2.1 Contaminant Distribution

Five analytes were selected for graphical presentation and assessment of contaminant distribution in the Basin F IRA area: DIMP, DBCP, dieldrin, chlorofom, and fluoride. These analytes were chosen because they are representative of a range of contaminant mobilities and compound groups present on RMA. DIMP and dieldrin are two of the most widespread and consistently detected semivolatile compounds and exhibit a wide range in behavior and toxicity. DIMP is a highly mobile contaminant, while dieldrin has low solubility and is relatively immobile in groundwater but has comparatively high toxicity. Dieldrin is also representative of the organochlorine pesticide compound group. Chloroform and DBCP are the most widespread and consistently detected volatile organic compounds and are important in evaluating the effectiveness of the NBCS and NWBCS. For the 1992 GMP, fluoride was chosen as a representative inorganic constituent for comparison purposes. However, fluoride is also a naturally occurring anion in groundwater and the assessment of fluoride contamination in the groundwater system includes a comparison with a concentration that is considered representative of background fluoride levels at RMA.

The areal extent of the five selected compounds in the unconfined and confined flow system are discussed in the subsections that follow. Overall variations were assessed by comparing the Winter 1992 analytical data to the Winter 1991 and Fall 1989 results presented in the Annual Groundwater Monitoring Report for 1991 (HLA, 1991) and evaluating historical trends through the use of histograms. Fall 1989 plume boundaries were not reconfigured for this report due to the limited 1992 GMP sampling network. Although plume maps are shown for the entire regional area, sampling of only the benchmark Basin F network during the Winter 1992 monitoring event limits comparison of the data to the Basin F area only.

Sample concentrations from wells that exhibited differences in concentration from Winter 1991 data and/or the contoured concentration ranges for Fall 1989 were compiled and summarized to identify deviations with historical trends or potential laboratory discrepancies. These wells and their concentration levels are listed in Table 4.22. Winter 1992 results which differed significantly (> 10-fold) from historical data, were considered anomalous if other data

were consistent and these data were not posted on the confined or unconfined flow system contaminant distribution maps. This 10-times approach was used to account for different field crews and/or laboratory discrepancies. Those wells displaying anomalous analytical results are summarized in Table 4.23. Values within the 10-times criteria show a somewhat static groundwater system.

Isoconcentration maps for the confined flow system were not created because of the limited number of wells sampled in the Denver Formation confined zones. However, a description of confined flow system contamination and a comparison with the previous year's distribution is also included for each analyte discussion. For the Basin F water-quality network, the groundwater data evaluation (HLA, 1994) reclassified five 1992 GMP confined flow system wells to an unconfined flow system and five 1992 GMP wells were changed to an unknown flow system. The wells reclassified to an unknown flow system are identified in Table 3.2 and Figure 3.3 with a star. Data for the unknown flow system wells are included in Appendices A through C (on diskette) but are not presented on the statistical data tables (Tables 4.18 through 4.21) or contaminant plume maps. Table 4.24 summarizes specific analyte water-quality results for the unknown flow system wells.

Diisopropylmethylphosphonate (DIMP)

DIMP was reported in eighty-two of ninety-eight investigative samples. Concentrations ranged from 0.769 to 2600 micrograms per liter (μg/l). Table 4.21 summarizes the analytical data for DIMP in the unconfined and confined flow systems. Figure 4.5 illustrates Fall 1989 DIMP plumes in the unconfined flow system with Winter 1992 analytical results posted.

Unconfined Flow System The areal distribution of DIMP in the unconfined flow system in the Basin F area has not changed significantly since Fall 1989 and reflects the somewhat static water-quality conditions observed in the Basin F area since 1989. Winter 1992 analytical data are generally consistent with the Fall 1989 DIMP plume map; however, changes are noted in Sections 23 and 26 due to the addition of reclassified confined Denver flow system wells to the unconfined flow system sampling network, as well as new data from wells not sampled or reported in Fall 1989. Table 4.22 summarizes and compares Winter 1992 and 1991 chemical data for wells that displayed concentration levels outside the Fall 1989 plume boundaries. As shown on Table 4.22 for DIMP analyses, five reclassified confined Denver flow system wells exhibit concentrations significantly below the Fall 1989 inferred contoured concentration area.

The eastern plume boundary can be extended slightly to the east to include Well 23155, a confined flow system well that is now classified as unconfined flow system well.

To further clarify interpretation of data discrepancies, the reclassified confined flow system wells and associated chemical data were posted on the Fall 1989 DIMP plume map using a different symbol. Those wells that displayed significant variance from the contoured concentration range in a DIMP contaminated area include site ID's 23221, 23189, 23180, 26149, and 26140. These wells are screened at a greater depth than the shallow alluvial wells and localized stratigraphic discontinuities may hydraulically separate these wells from the contaminated alluvial system.

Three wells in Section 26 (26020, 26085, and 26170), not sampled or data not reported during the 1990 and 1991 water monitoring years and located adjacent to or on the inferred plume boundary lines, show levels slightly above or below the contoured concentration limit. Plume boundaries can be reconfigured in the vicinity of Well 23191, which has shown a slight decrease in DIMP since 1991 (73 μg/l in 1991, 50 μg/l in 1992). In contrast, alluvial cluster well 23188 has displayed an increase in DIMP, above 1989 concentration levels, since 1991 (620 μg/l in 1991, 1200 μg/l in 1992). However, concentration fluctuations for both of these wells are within the 10-times criteria which allows for variations due to field sampling technique and discrepancies between laboratories.

Histograms of DIMP concentrations for wells near Basin F (Figure 4.6) show generally decreasing to consistent concentrations from wells in the vicinity of Basin F since monitoring began in 1978. Two wells displayed isolated increases in DIMP and deviated from the general decreasing trend during one monitoring event in 1992. Well 23049, located adjacent to the temporary storage ponds, exhibited a seven-fold increase in concentration during Summer 1992, when compared to Winter 1992 and historical data. Well 23220, located just north of the liquid storage tanks, also showed an isolated concentration increase in Summer 1992, when compared to the Winter 1992 data. As illustrated on Figure 4.6, DIMP levels for this well had appeared to be steadily decreasing since 1990. Analytical data collected during 1993 will determine whether the increases in these wells are isolated occurrences. Well 23095 also showed slight increases in DIMP compared to the 1991 data, although in general, concentration levels have remained fairly constant since 1988.

Confined Flow System. DIMP was only detected in one confined flow system sample (Well 26129) analyzed during the Winter sampling event at a concentration of 1800 μg/l.

Figure 4.7 illustrates Winter 1992 DIMP detections within the confined flow system. The areal distribution for DIMP has remained at fairly consistent nondetect levels since 1989 and appears to be restricted to the area around Well 26129. Incomplete well construction exists for Well 26129 and water-quality data for this well may be suspect. Three wells in Section 26 that historically reported DIMP detections were reclassified as unconfined flow system wells and, therefore, are not shown on this Figure.

Dibromochloropropane (DBCP)

Analyses for DBCP were performed on ninety-two investigative groundwater samples collected from the unconfined flow system during the 1992 GMP. DBCP was reported in eighteen (23 percent) of these samples at concentrations ranging from 0.202 to 30 µg/l. Table 4.21 summarizes DBCP analytical results for the unconfined and confined flow systems. Figure 4.8 illustrates Fall 1989 DBCP plumes with Winter 1992 analytical results posted.

Unconfined Flow System. The configuration of the DBCP plume extending northeast out of the northern Basin F IRA area has not changed significantly since Fall 1989. Winter 1992 analytical results for DBCP are similar to the Fall 1989 and Winter 1991 data, with two exceptions. DBCP values from two wells in Section 23, listed in Table 4.23, that were not reported during the Fall 1989 sampling round, show concentration levels above the 1989 levels mapped for their location. Incorporating data from these wells extends the central DBCP (5.00 - 49.9 µg/l) plume slightly further north-northeast than interpreted from previous CMP data. No significant deviations from historical data or contoured concentration ranges for DBCP exist in the reclassified confined flow system wells. Histograms for DBCP (Figure 4.9) illustrate slight increases in concentration in Wells 26157 and 26133, located east of the temporary storage ponds, when compared to Fall 1989 levels. However, in general, DBCP levels have remained fairly static and at low concentration to nondetect levels since initiation of Basin F IRA activities in 1988.

Confined Flow System. DBCP was not detected in any confined flow system samples analyzed during the Winter 1992 sampling event. Figure 4.10 illustrates Winter 1992 DBCP data posted for confined flow system wells. The Winter 1992 DBCP distribution is similar to historical confined flow system data trends and shows that DBCP has consistently not been detected in the confined flow system in the Basin F area for the past two years. An isolated 1991 DBCP detection from a well in Section 26 was reclassified to an unconfined flow system

well and is, therefore, not shown.

Dieldrin

Ninety-four dieldrin analyses were performed for the 1992 GMP. Dieldrin was reported in seventy-seven (82 percent) of these samples at concentrations ranging from 0.054 to 8.2 μg/l. Table 4.21 summarizes the dieldrin analytical data for unconfined and confined flow system samples.

Unconfined Flow System. As discussed in the QA/QC analysis (subsection 4.3.1) dieldrin was detected in a rinse blank sample and data from five samples collected on the day the rinse blank are not usable. Data from these wells are not presented on the dieldrin contaminant plume map or Table 4.18. In addition, as shown on Table 4.23, four unconfined flow system wells exhibited anomalously elevated dieldrin values (> 10-fold) as compared to historic CMP data and these data are also not included on the plume map or Table 4.18. Laboratory QA/QC protocol was not strictly followed for dieldrin analyses (see subsection 4.3.1 for a detailed discussion). Because of dieldrin blank artifact contamination and laboratory QA/QC problems, not all Winter 1992 dieldrin water-quality data meets the 1992 GMP data quality objectives.

Figure 4.11 superimposes Fall 1989 dieldrin plumes for the unconfined flow system with Winter 1992 analytical results. A number of wells in Section 23 and 26 displayed slight increases in dieldrin concentration values that fell outside the contoured concentration range shown on the Fall 1989 plume configuration map. Many of these slight increases may be due to the laboratory dieldrin method problems described in earlier sections. Comparison to 1991 data is limited since most of the 1991 dieldrin samples collected in this area failed to meet PMRMA QA criteria and were placed in the rejected electronic file in the 1991 RMAED.

Some differences between the Fall 1989 plume map and the 1992 data are due to the addition of wells that were previously classified as confined flow system wells. Four reclassified confined flow system wells (23180, 23189, 23221, and 26146) exhibit concentrations less than CRL or within an order of magnitude below the contoured concentration range shown on the plume map.

Figure 4.12 presents histograms of dieldrin concentrations since 1979 for eighteen wells in the Basin F vicinity. Samples from most of these wells have shown consistent dieldrin detections of less than 2 μg/l since 1988, with erratic, isolated concentration increases in no apparent areal pattern. The 1992 increases and deviation from historical trends for dieldrin,

may reflect outside influences rather than contaminant increases in the unconfined flow system.

Confined Flow System. Figure 4.13 illustrates Winter 1992 dieldrin data for the confined flow system. Dieldrin was detected slightly above the CRL from two wells in Section 26 that exhibited concentrations less than the CRL for the Fall 1989 and Winter 1991 sampling rounds. Dieldrin was detected in Well 26084 at a higher concentration level during Fall 1989 than Winter 1992. The isolated dieldrin detection in Section 23 is consistent with historical levels for that well.

Chloroform

Analyses for chloroform were performed on seventy-seven investigative groundwater samples for the 1992 GMP. Chloroform was reported in thirty-six (47 percent) of these samples at concentrations ranging from 0.657 to 65,000 μg/l. Table 4.21 summarizes chloroform analyses for the unconfined and confined flow system wells. Figure 4.14 illustrates Fall 1989 chloroform plumes for the unconfined flow system with Winter 1992 analytical results posted.

Unconfined Flow System. Winter 1992 chloroform data is similar to historical CMP chloroform distributions. The primary differences are related to the addition of reclassified confined flow system wells to the Fall 1989 plume map. Table 4.22 summarizes Winter 1992 chloroform analyses differences between Fall 1989 contoured concentration range and Winter 1991 data. The addition of Well 23155, a reclassified confined flow system well, extends the 10 to 99.9 μg/l plume boundary further to the east. Three reclassified confined flow system wells (23180, 23189, and 23221) in Section 23 exhibit concentrations below the CRL or significantly below the contoured concentration range of 100 to 999 μg/l for that area. Well 23189 has also shown steady decreases in chloroform levels since 1989 (Table 4.22). Well 26149, also reported as less than the CRL, is located in a high chloroform contamination area contoured for concentration levels between 1000 to 9,999 μg/l. The impact on plume reconfiguration and correlation with the contaminated alluvial system for these reclassified wells is not fully understood and will be evaluated in future unconfined flow system groundwater studies.

Chloroform concentration histograms are presented in Figure 4.15. Chloroform concentrations are low-level and have remained fairly constant for most wells located northwest of the solid waste pile since initiation of Basin F IRA activities. Quarterly concentration

increases and decreases relative to historical data are observed in individual wells (26133, 26073, 26157, 23095, and 23049) located north and east of the temporary storage ponds. Well 26085, located in Basin C, has shown a steady slight decrease in chloroform concentration since 1990. However, slight increases or decreases of chloroform at low levels are probably not significant since chloroform has been identified as a potential laboratory contaminant (see subsection 4.3.1).

Confined Flow System. Chloroform was not detected in any of the confined flow system samples analyzed during the Winter 1992 sampling event. Figure 4.16 illustrates Winter 1992 chloroform data posted for the confined flow system. The lack of chloroform detections in the wells sampled during Winter 1992 is consistent with historical data and reflects static water-quality conditions for chloroform in this area. Isolated chloroform detections reported in Section 23 during Fall 1989 and Winter 1991 were from wells now reclassified to the unconfined flow system.

Fluoride

Fluoride analyses using method TT09 were performed on ninety-nine investigative groundwater samples during 1992 GMP. Fluoride was reported in ninety-seven (98 percent) of these samples at concentrations ranging from 1680 to 270,000 μg/l. Table 4.21 summarizes fluoride analytical data for unconfined and confined flow system samples.

Fluoride is a naturally occurring constituent of groundwater. Samples collected upgradient of RMA between 1964 and 1976 reported fluoride concentrations ranging from 570 to 4850 μg/l, indicating that background concentrations may be highly variable. The background concentration of fluoride estimated from 1989 data in wells upgradient of RMA was 1390 μg/l (Stollar et al., 1991). To define fluoride contamination, a concentration of 2,000 μg/l was used as the lowest contour in constructing the Fall 1989 plume map (Stollar and others, 1991). The QA review of available Winter 1992 fluoride data packages showed that chloride interference using method TT09 may have impacted data results by increasing concentrations from two to 20 times (see QA/QC subsection 4.3.1.4). Future GMP fluoride analyses will use method TU02.

Unconfined Flow System. Figure 4.17 illustrates Fall 1989 fluoride plumes with Winter 1992 analytical results posted. The fluoride plume extending northeast out of the northern Basin F IRA area shows fluctuating values for some wells and similar values for other wells

when compared to historical data. In general, 1992 fluoride data show decreased concentration levels, as compared to 1991 and 1990. Four wells in Section 23 and four wells in Section 26 show diminished concentrations in Winter 1992 and fall outside the 1989 plume boundaries. Two of these wells also showed decreased fluoride levels in Winter 1991. All of the reclassified wells display fluoride concentrations similar to or less than that contoured on the plume map except for an individual concentration increase from 1991 levels for Well 26066. Many of these deviations are probably related to natural water chemistry fluctuations of fluoride in the groundwater.

Histograms of fluoride concentrations are presented in Figure 4.18. The histograms illustrate that fluoride levels have historically fluctuated quarterly in an apparent random pattern in the Basin F IRA area. However, the histograms do show that fluoride levels for 1992 were generally similar to or less than historical data. Elevated CRLs during 1991 created difficulty in interpreting fluoride concentration levels.

Confined Flow System. Figure 4.19 illustrates Winter 1992 fluoride detections within the confined flow system. Historical CMP confined flow system fluoride data do not show significant differences from Winter 1992 data, with the exception of one well in Section 26 (26153). The Winter 1992 fluoride concentration for Well 26153 was 2830 μg/l, but was less than the CRL (153 μg/l) during the Fall 1989 and Winter 1991 monitoring events. However, changes in the overall fluoride distribution within the Denver Formation from Fall of 1989 to Winter 1992 remained relatively minor.

n-Nitrosodimethylamine (NDMA)

A total of nine (eight unconfined flow system wells and one confined flow system well) NDMA analyses were performed during the 1992 GMP at Datachem laboratory. NDMA was analyzed using GC/MS method UM-25. Five samples were collected from unconfined flow system wells (23221, 23237, 26015, 26149, and 26169) during the Winter 1992 sampling event. NDMA was only detected in one sample (26169) near the Basin F temporary solid waste pile at a concentration of 31 μg/l during the Winter sampling event. Tables 4.18 through 4.20 summarize NDMA analytical data for 1992. NDMA contaminant plume maps were not constructed because of insufficient areal coverage and lack of detections for the Winter 1992 sampling round.

4.3.2.2 Influences on Data Interpretation

Interpretation of 1992 GMP analytical data was influenced by laboratory analyses and reporting variables, as well as changes to the water-quality sampling network by additions or deletions of wells with reclassified flow system designations. Laboratory analysis and reporting influences were discussed in subsection 4.3.1.

Although fewer wells were sampled during the 1992 GMP than during the 1991 or 1989 CMP field programs, the addition of eight reclassified confined Denver flow system wells to the unconfined Basin F sampling network resulted in a number of changes to the 1989 plume configurations in the Basin F IRA area. The following is a summary of locations where detected analyte values in reclassified confined flow system wells were higher or lower than expected at that location, when compared to the Fall 1989 plume maps:

- o DIMP levels were lower than expected, based on concentrations in neighboring wells, from three wells in Section 23 and two wells in Section 26.
- o Dieldrin levels were slightly lower than expected, based on concentrations in neighboring wells, from two wells in Section 23 and one well in Section 26, and higher than expected from one well in Section 26.
- o Chloroform levels were lower than expected, based on concentrations in neighboring wells, from two wells in Section 23.
- o Fluoride was detected slightly below expected concentration levels in samples from four wells in Section 23, three wells in Section 26, and above expected levels from one well in Section 26.

4.4 CONCLUSIONS

The 1992 GMP water-level and analytical data were compared to historical data on a regional and well-specific basis. General trends in contaminant distribution for DIMP, DBCP, dieldrin, chloroform, and fluoride were evaluated throughout the Basin F IRA area. Significant observations and conclusions based on the 1992 GMP data are listed below.

1. Confined flow system reclassifications from the recently completed Groundwater Data Evaluation (HLA, 1994) were incorporated into the 1992 GMP database to provide updated technical information for the 1992 GMP Annual Report. The

number of wells that were reclassified for the 1992 GMP include:

- o 125 confined Denver wells changed to unconfined
- o 45 confined Denver well changed to unknown
- o 1 unconfined well changed to unknown
- o 5 wells without designations (no designation) changed to unconfined
- o 6 no designation wells changed to confined
- o 1 no designation well changed to unknown

The 1992 GMP water-level and analytical database were greatly impacted by these flow system reclassifications. The confined flow system reclassifications significantly reduced the number of confined flow system wells and produced insufficient areal coverage of the multiple potentiometric zones contoured for previous CMP Annual Groundwater Reports.

2. The general configuration of the regional water-table is similar to that shown during the 1991 CMP and previous monitoring years. This consistency indicates that regional groundwater flow patterns also remain constant. The configuration and level of the regional water-table surface remained relatively constant from Winter through Summer 1992. Water-levels were lowest during the Summer quarters, especially in an area southwest of the ICS. The regional slope of the water-table is from southeast to northwest. Groundwater flow follows the slope of the bedrock surface and discharges to the South Platte River, approximately two miles northwest of RMA. The South Platte acts as a major discharge area for the regional unconfined flow system. Groundwater flow along the north and northwest boundaries at RMA has been modified by systems operations of the NBCS and NWBCS. Deviations from regional patterns are observed in these areas and in the vicinity of the ICS.

3. Vertical gradients calculated for well pairs and well clusters throughout RMA indicate that downward vertical gradients predominate between unconfined/confined flow system wells, the magnitude of which lessens toward subcrop areas. Upward gradients existed in slightly less than half of the unconfined alluvial/Denver Formation well cluster sites. This suggests that lithologic stratification, discontinuous clay and sand lenses, and other geologic factors exist in the unconfined flow system that may cause localized gradient variations.

4. Data quality objectives were met for the 1992 GMP for precision, accuracy, representativeness, comparability, and completeness for all data except Winter 1992 dieldrin and fluoride analyses. Data packages for suspect dieldrin and fluoride results were missing and could not be verified. Dieldrin field rinse blank artifact contamination affected five samples and historical comparisons resulted in ten unusable dieldrin data for the Winter 1992 data set. Available dieldrin chromatograms were reviewed and were categorized as a "picket fence" or Type III sample. Laboratory QC confirmational GC/MS analyses for these data were not performed. At least ten dieldrin analyses, and possibly many of the

other pesticide analyses performed during the 1992 GMP, are not representative of the groundwater chemistry.

5. The areal distribution of DIMP in the unconfined and confined flow system has not changed significantly since the major baseline sampling and completion of Basin F excavation in 1990. Discrepancies between 1992 GMP and the Fall 1989 plume maps are primarily due to the addition of reclassified confined flow system wells to the unconfined flow system sampling network and new data from wells not previously sampled. Histograms of DIMP concentrations since 1978 also show generally decreasing to constant conditions. Isolated increases in two wells during the Summer quarter appear anomalous and future sampling will indicate whether additional quarterly monitoring should be required. DIMP distribution reflects water-quality conditions that have remained relatively static in the Basin F area.

6. DBCP was detected in 14 percent of the samples collected during the Winter 1992 from the unconfined flow system and was not detected in any confined flow system well. The only deviations from the plume map were from two wells that had not been sampled during the Fall 1989 quarter. Histograms of DBCP concentrations also illustrate that DBCP levels have remained consistent with historical levels or at low to nondetect concentrations since initiation of Basin F IRA activities.

7. An accurate assessment of the areal distribution for dieldrin during the 1992 GMP was complicated by laboratory QC method problems and potential field rinse blank artifact contamination. A number of samples in Sections 23 and 26 displayed erratic concentration increases and decreases in no apparent areal pattern throughout the Basin F area. Comparison to 1991 CMP data was limited since most of the 1991 dieldrin analyses failed to meet PMRMA QA objectives and were rejected by PMRMA LSD.

8. Chloroform was detected in 30 percent of Winter 1992 unconfined flow system samples and was not detected in any confined flow system wells. The areal distribution for chloroform during the 1992 GMP was consistent with historical data. Primary differences are related to the addition of reclassified confined flow system wells to the unconfined flow system network. The lateral extent and concentration range for chloroform in the Basin F area has not changed significantly since completion of excavation and IRA activities in 1990.

9. Fluoride is a naturally occurring compound and was detected in all the Winter 1992 samples collected from the unconfined and confined flow system. The plume of elevated fluoride levels extending northeast out of the northern Basin F area shows fluctuating values for some wells and similar values for other wells when compared to historical data. Histograms illustrate that fluoride levels have historically fluctuated quarterly in an apparent random pattern in the Basin F area. However, fluoride levels for the 1992 GMP were generally less than or similar to historical data. Changes in the overall fluoride distribution within the confined Denver Formation have remained relatively minor. An elective fluoride

method (TU02) reviewed in the Pre-QC electronic file for Summer 1992 analyses showed fluoride results two to 20 times lower than the TT09 method normally used for fluoride analyses. The TU02 method is now being used for fluoride analyses for the continuing GMP.

10. The 1992 GMP data and areal contaminant distribution is generally comparable with historical CMP data and reflect water-quality conditions that have either declined or not changed significantly in up or downgradient wells since initiation of Basin F IRA activities in 1988. Water-quality discrepancies between the 1989 plume contours and the 1992 posted values are mainly attributed to the addition of reclassified confined Denver Formation flow system wells to the unconfined flow system sampling network. These wells generally exhibited concentrations less than that shown on the Fall 1989 plume maps. The impact on plume reconfiguration and the correlation of these wells with the contaminated alluvial system will be evaluated during future GMP studies.

5.0 ASSESSMENT OF 1992 WATER MONITORING YEAR DATA FOR INTERIM RESPONSE ACTION AREAS

Five IRA areas at RMA were previously selected by the Army for accelerated remedial actions because of the potential they represented for contaminant migration to offpost areas or because the IRAs would provide significant beneficial effects on the groundwater system. These areas include the NBCS, NWBCS, Basin F IRA area, BANS, and ICS. The objectives of this section are to assess the hydraulic impact of the IRA activities on groundwater flow and contaminant distribution. A summary of lateral contaminant distribution in the Basin F area, while discussed in subsection 4.3.1, is also reviewed for this Section, as well as vertical contaminant migration.

Evaluations of groundwater flow in the IRA areas were based on water-level data collected between October 1, 1991, and September 30, 1992, from the GMP and TOD well networks. TOD data were collected either weekly or monthly, and GMP data were collected for the Winter, Spring, and Summer 1992 quarters. The TOD network is a dense local well network compared to the GMP network and the wells are generally located close to the NBCS and NWBCS. The 1992 GMP groundwater sampling network did not include sufficient analytical data for contaminant migration assessment near the NBCS, NWBCS, or BANS. Groundwater quality data collected by MKE for the Northwest, North, and Basin A-Neck Treatment Plants were obtained for these areas and are presented on histograms. The analytical database provided by MKE for the NBCS, NWBCS, and BANS is included in Appendix D (on diskette).

The following sections detail groundwater flow and contaminant distribution and migration (where data were available) for the NBCS, NWBCS, BANS, and Basin F IRA areas. Because analytical data were not collected in the area of the ICS during the 1992 water monitoring year, only a discussion of groundwater flow is presented for this IRA.

5.1 WATER-QUALITY DATA

The 1992 GMP groundwater sampling network for the boundary systems area included two wells (23202 and 23204) near the NBCS that were only sampled during the Summer quarter. Supplemental data collected by MKE were obtained to provide a more complete review of contaminant distribution for the boundary systems.

Data collected by MKE was analyzed by ESE-Denver during the first through third

quarters of 1992 for wells in the NWBCS using GC/MS methods. Gas chromatography-specific methods were only performed for the pesticides, DIMP, DBCP, DMMP, DCPD, and MIBK. Anions and metal analyses were not performed. Samples collected during fourth quarter in the NBCS, NWBCS, and BANS area were analyzed at Vista and ESE-Denver laboratories using USEPA SW846 methods. Data for both the Army and EPA-certified methods are presented for interpretational purposes since the methods are comparable. Table 5.1 summarizes the method numbers, laboratories, CRLs, and USEPA detection limits for four analytes (DIMP, DBCP, dieldrin, and chloroform) presented on histograms. Fluoride analyses were not performed for the wells shown on the histograms. Analyses for the four analytes were not consistently performed during each sampling quarter. Data not obtained for a well was flagged as "No Data Available" on the histogram.

5.2 NORTH BOUNDARY CONTAINMENT/TREATMENT SYSTEM

The NBCS consists of a soil-bentonite barrier wall that extends approximately 6,740 feet along the northern boundary of RMA. Extraction wells south of the barrier wall pump groundwater to the NBCS treatment facility where it is treated using a granular activated carbon treatment system to remove organic contaminants. Recharge trenches north (downgradient) of the barrier wall recharge treated water to the unconfined flow system. Before 1988, recharge wells were used instead of the recharge trenches. Trenches were installed in 1988 and 1990 to provide increased recharge capacity downgradient of the wall to in turn produce a reversal in hydraulic gradient (i.e., reversal of the northerly regional gradient) across the wall. Recharge trenches installed along the western half of the barrier wall became operational in October 1988, and those installed along the eastern half became operational in July 1990. A reversal in hydraulic gradient is insurance against migration of contaminants to the north of RMA.

During the 1992 water monitoring year, IRA activities at the NBCS consisted of continued testing of the five recharge trenches installed along the eastern half of the NBCS. In addition, injection rates in the western trenches were varied to help establish and maintain a reversal in hydraulic gradient along the entire NBCS barrier wall.

5.2.1 Groundwater Flow

All available 1992 data from the three GMP water-level monitoring events, weekly or biweekly TOD data, and supplemental USGS data were used to evaluate groundwater flow conditions in the NBCS area. TOD data can be obtained in the RMAED and are included in annual reports for the NBCS and NWBCS (PMRMA, in preparation). Figure 5.1 shows the water-level monitoring well locations in Sections 23 and 24 for the NBCS. Monitoring well locations in the vicinity of the South Plants Tank Farm are shown, but this IRA is not discussed due to limited available data in the RMAED for this area.

Water-level measurement dates and the respective quarter designations used for the water-table contour maps are listed below:

Date	1992 Quarter
December 3 to December 18, 1992	Winter
March 3 to March 31, 1992	Spring
June 2 to June 12, 1992	Summer

5.2.1.1 Water-Table Maps

Figures 5.2 through 5.4 illustrate the generalized water-table surface for the boundary systems. These maps were constructed using a 2-foot contour interval to show a more detailed presentation of seasonal variations in the water-table configuration than that illustrated on the regional maps (Figures 4.1 through 4.3). The major hydrologic impacts of NBCS operations on the unconfined flow system in this area include:

- A local flattening of the water-table south of the barrier wall
- A steepening of the water-table just north of the barrier wall
- Localized mounding from systems operations of recharge wells, and recharge trenches

Seasonal water-level fluctuations in the vicinity of the NBCS were generally less than two feet between the Winter, Spring, and Summer quarters. However, water-levels were up to six feet lower during the Winter quarter in some downgradient wells on the eastern end of the barrier wall, as compared to the Spring and Summer quarters. All three maps show that

head levels north of the barrier were one to two feet higher than south of the barrier throughout the length of most of the system. A reverse gradient to the south did not occur along the eastern 1,200 feet of the wall during the Winter quarter, but was achieved during the Spring and Summer quarters.

5.2.1.2 Water-level Cross-Sections

Cross-sections illustrating the water-table surface along the trace of the barrier system (west to east) were prepared for the four quarters of 1992 (Figures 5.5 through 5.8). Water-level elevations for wells located both north and south of the barrier wall were projected onto the cross-sections to identify hydraulic gradient conditions. The water-level elevations used to construct the cross-sections are averaged values of all water-level data collected at each well during the respective quarters. The periods for which the cross-sections were prepared, data sources, and quarter designations used in the following discussion, are as follows:

Date	Data Sources	Quarter
October 1 to December 31, 1991	GMP, TOD, USGS	First
January 1 to March 31, 1992	GMP, TOD, USGS	Second
April 1 to June 30, 1992	GMP, TOD, USGS	Third
July 1 to September 30, 1992	TOD, USGS	Fourth

Water-level elevations presented on the cross-sections were collected between the dates specified above, whereas the potentiometric data used for the water-table maps were collected only during the GMP monitoring dates specified. Therefore, these figures cannot be directly compared to one another.

The first quarter water-table elevation cross-section is shown on Figure 5.5 and illustrates that a reversal in hydraulic gradient (greater than two feet) existed in the unconfined flow system along the length of most of barrier wall to just beyond Well 24514. This reversal is highlighted on the cross-sections by a hatchured pattern. Hydraulic head levels along the eastern 1200 feet of the wall were approximately two to six feet higher on the south (upgradient) side compared to water-levels north (downgradient) of the wall. Lateral hydraulic gradients across the barrier wall were primarily to the south (reversed) and ranged from less than 0.03 to 0.01. A northward (normal) gradient of approximately 0.05 was observed along the eastern 1,200 feet of the wall.

As illustrated on Figure 5.5, there are a limited number of wells available for data interpretation south of the wall and it was necessary to extrapolate the upgradient potentiometric surface over much longer distances than was required on the downgradient (north) side. An area of potential nonreversal during the first quarter may have occurred at the bend in the wall in the vicinity of Well 23527. However, most of the southern potentiometric surface in this area was interpolated approximately 700 feet; therefore, the precise location of lateral gradients for this area cannot be calculated.

During the second quarter, a reversal in hydraulic gradient was achieved along a greater length of the wall, except for approximately 400 feet in the vicinity of Well 24515 (Figure 5.6). As previously discussed, the discrepancy in this area may be a result of limited water-level data south of the barrier wall. Hydraulic gradients across the wall were primarily southward (reversed) and ranged from 0.002 to 0.74. Slight northward gradients ranging from 0.001 to 0.004 existed along the eastern 400 feet of the wall in the vicinity of Well 24518.

Figure 5.7 illustrates that during the third quarter a reversal in hydraulic gradient existed along the entire length of the barrier wall to Well 24520. However, the hydraulic head levels in wells across the wall declined to 1-foot and less for approximately 950 feet between Wells 24193 and 24511. Lateral gradients ranged from 0.003 to 0.11 and were consistently to the south (reversed) and generally higher than in the first and second quarters near the central portion of the wall.

During the fourth quarter, a reversal in gradient existed along the entire length of the wall to Well 24520 (Figure 5.8). Hydraulic head-levels across the wall were 1-foot and less for approximately 1,700 feet between Wells 24194 and 24517. Lateral gradients were consistently to the south (reversed) and ranged from 0.01 to 0.03.

5.2.1.3 <u>Groundwater Hydrographs</u>

The NBCS was designed to remove and treat contaminated groundwater in the alluvial groundwater system before it migrates offpost. It is the Army's operational goal to maintain a reverse hydraulic gradient in the unconfined and achieve the goal of preventing offpost migration of contaminated alluvial groundwater in the unconfined flow system. To assess flow within and between the unconfined and confined flow systems, groundwater hydrographs are presented to evaluate the following:

- o Lateral hydraulic gradients across the barrier wall within the unconfined flow system
- o Lateral hydraulic gradients across the barrier wall within the confined flow system
- o Vertical hydraulic gradients between the unconfined and confined flow systems, both north and south of the barrier wall

Locations for the wells presented on the hydrographs in relation to the barrier wall are shown on Figure 5.1. Figures 5.9 through 5.12 present hydrographs that illustrate hydraulic conditions in the unconfined flow system along most of the length of the barrier wall. Each of these hydrographs show water-level data for two wells close to one another on the north and south side of the barrier wall. The wells shown on the hydrographs illustrate a consistent reversal in hydraulic gradient throughout the four quarters of monitoring. Water-levels in Well 24512 decreased close to the level of Well 24180 (Figure 5.9), near the end of the first and beginning of the second quarter. However, a reversal in hydraulic gradient was achieved throughout the remaining portion of the year. Well 24177 has historically been used for evaluating vertical gradients in this area but was dry throughout most of the second to fourth quarters with water-level measurements only recorded during the first quarter and one week of the third quarter and, therefore, was not used data evaluation for this report. This well has recently been shown to be silted in and, although the well is recorded as dry, saturated alluvium may exist in this area.

Hydrographs for two pairs of confined wells (Figures 5.13 and 5.14) were prepared to evaluate lateral hydraulic gradients within the confined flow system near the NBCS. Well 23234 (located south of the barrier wall) was reclassified to an unconfined flow system with questionable data and was not used for this analysis. Figures 5.13 and 5.14 present water-level data for two wells in Section 24 that are north and south of the barrier wall and in close proximity to each other. Water-levels for these wells were only taken during the three 1992 GMP monitoring events. Data for both sets of well pairs show that a normal regional gradient existed within the confined Denver flow system during the Winter and Spring quarters, and a slight reversal in gradient occurred during June 1992. However, the hydraulic head north of the wall, at Well 24202, was only 0.2 feet higher than the head at Well 24202, south of the wall. This slight head difference also existed during the 1991 water monitoring year and indicates that hydraulic gradient reversals in this area are slight and may change as a result of seasonal or normal fluctuations in the data. Data points separated by more than two months are not

connected by lines on the graphical presentations, as this represents an excessive interpolation.

Groundwater hydrographs were prepared for four well clusters located along the length of the barrier wall to evaluate vertical hydraulic gradients between the confined/unconfined flow systems, and unconfined alluvial/ Denver Formation flow system wells (Figures 5.15 through 5.18). Confined Denver flow system wells that were reclassified to unconfined Denver flow system were also used in this analysis. Three of these clusters are north of the wall and one is south of the wall, as shown in Figure 5.1. Limited water-level data was available for many of the confined and unconfined Denver flow system wells cluster wells south of the wall that had been evaluated in previous years. A well cluster is defined as a set of wells completed at different depth intervals that are spatially close to one another. Cluster wells averaged approximately 50 feet from one another with a maximum distance of approximately 200 feet. Table 5.2 summarizes vertical gradient directions at these cluster locations.

All three hydrographs of well cluster sites north of the barrier (Figures 5.15 through 5.17) reflect downward gradients (Table 5.2) and show that hydraulic head-levels in the unconfined alluvial flow system were consistently higher than in the underlying confined Denver Formation. Figure 5.15 also illustrates that heads in unconfined alluvial Well 24522 and unconfined Denver Well 24172 are close in elevation.

Figure 5.18 presents hydrographs of cluster wells located south of the NBCS in Section 23. The hydrographs indicate that heads in the unconfined alluvial and Denver flow system were very similar, yet a slight upward gradient existed for most of the year between alluvial well 23178 and unconfined Denver flow system Wells 23176 and 23177. Slight upward gradients were also observed between these wells during the 1991 water monitoring year. Upward gradients are favorable in this area since they inhibit downward migration of contaminants from the unconfined flow system to the confined flow system upgradient of the barrier wall. Vertical gradients on the north side of the NBCS should currently be downward due to the re-injection of water to reverse the gradient direction across the barrier wall.

5.2.2 Contaminant Migration

Contaminant migration at the NBCS was evaluated for the unconfined flow system through the use of water-quality histograms. Water-quality data collected in this area was limited to two wells sampled by the Army during the second quarter (23202 and 23204) and eight wells

sampled by MKE during the fourth quarter. The following data comparison discussions are limited to only the wells with available analytical data for the 1992 water monitoring year.

5.2.2.1 Unconfined Flow System

Contaminant migration and temporal trends for the unconfined flow system at the NBCS were evaluated through the use of histograms for DIMP, DBCP, dieldrin, chloroform. Fluoride analyses were not performed for the wells sampled during 1992 in this area. The histograms were used to assess increases or decreases in concentrations that could be related to the effectiveness of the NBCS in preventing offsite migration of contaminants.

Figures 5.19 through 5.22 present histograms of contaminant concentrations through time for selected wells screened in the unconfined flow system. The selected wells were chosen on the basis of the following criteria:

- o They were part of the GMP network.
- o They provide an adequate areal distribution of data in the area of the NBCS.
- o They had long-term historical data.
- o They were wells of potential concern (i.e., those having high concentrations historically).

Figure 5.19 illustrates histograms of DIMP concentrations since 1978 for twenty-one wells near the NBCS. For 1992, data was available for eight out of the twenty-one histograms shown on Figure 5.20. Analytical data for wells located south (i.e., upgradient) of the barrier wall were not available.

Concentrations of DIMP downgradient of the barrier wall have decreased significantly since recharge trench startup (i.e., from >100 to <12 μg/l) in samples from Wells 23202 and 23204, screened in the unconfined Denver just below the recharge trenches. These decreases are likely a result of dilution from recharge to the trench. Samples from downgradient wells 23226, 23235, and 37339 also show a significant decrease in DIMP concentration since startup of the recharge trenches. Downgradient Wells 37338, 37312, and 37307 have shown fairly constant DIMP levels (low to nondetect) since 1988.

Figure 5.20 presents histograms of DBCP concentrations since 1978 for nineteen wells near the NBCS. Data was only available for five of the nineteen wells shown on the

histograms. No data was available for wells located upgradient of the NBCS.

DBCP has been reported sporadically downgradient of the barrier wall in recent years. However, DBCP was not reported in any of the wells sampled during 1992. A low concentration of DBCP just slightly above the CRL was reported in samples from Well 24191 in 1991, but was not reported in September of 1992.

Figure 5.21 presents histograms of dieldrin concentrations since 1979 for twenty-one wells near the NBCS. Dieldrin analyses were available for seven out of the twenty-one wells located in this area for 1992. Dieldrin was only reported in one (37312) of the seven wells (23202, 23204, 23226, 37339, 37307, 23235) sampled north of the barrier wall during 1992. As shown on Figure 5.21, these wells have historically shown no dieldrin detections (except for Well 37312 and an isolated detection in Well 37307 in 1989). Dieldrin continues to be detected, at fairly consistent low concentrations (<1 μg/l), in Well 37312, located 300 feet downgradient of the recharge trenches. Dieldrin has not been reported, since startup of trench operations in 1988, in samples from Well 23204, an unconfined Denver flow system well located below a recharge trench. Likewise, dieldrin has never been reported in unconfined Denver Well 23202.

Figure 5.22 illustrates chloroform concentration histograms for seventeen wells in the vicinity of the NBCS. Chloroform analyses for these wells were not performed until 1986. Data for wells located south of the barrier wall were not available. A relatively abrupt decrease in concentrations is evident in samples from some wells downgradient of the wall, coincident with startup of the initial recharge trenches in October 1988. Chloroform detections remained relatively constant in samples from other downgradient wells, except for a slight increase in Wells 23202 and 23204. Chloroform has consistently been detected below 1 μg/l or less than the CRL for these wells since 1989. Slight changes in contaminant concentrations among sampling events may either reflect seasonal changes, field sampling and decontamination technique, variations in analytical technique, or laboratory artifact contamination. Additional sampling at these wells will determine whether these chloroform detections are anomalous.

No 1992 data was available for offpost wells located north of RMA and downgradient of the NBCS. Thus, concentration histograms are not presented for offpost wells.

5.3 NORTHWEST BOUNDARY CONTAINMENT/TREATMENT SYSTEM

The NWBCS was designed to prevent the migration of contaminants, particularly DBCP, offpost to the northwest of RMA. Recent improvements to the NWBCS were made primarily

because of the presence of dieldrin offpost and northwest of RMA that was apparently bypassing the original system. The original system, which became operational in January 1984, consisted of a soil-bentonite barrier wall, approximately 1,425 feet long, and a system of extraction and recharge wells approximately 2,300 feet long designed to form both a hydraulic and physical barrier. The hydraulic barrier portion (southwest extension) of the system extends 900 feet southwest of the barrier wall and consists of a series of extraction wells spaced 100 feet apart and recharge wells spaced 75 feet apart along the southwest portion of the barrier and 150 feet apart along the northeast portion of the barrier system. Another series of extraction and recharge wells is located on either side of the barrier wall. Groundwater is extracted and treated using an activated carbon treatment system to remove organic contaminants and is then recharged to the unconfined flow system via recharge wells downgradient of the barrier wall.

The Army and Shell instituted improvements to the NWBCS because an alluvial channel had been identified northeast of the original NWBCS that would allow contamination to bypass the system. These improvements included a 665-foot-long extension at the northeast end of the barrier wall that was added during 1990 and two new groundwater extraction wells at the southwest extension.

5.3.1 Groundwater Flow

All available water-level data collected during the 1992 water monitoring year were used to evaluate the impact of the NWBCS on groundwater flow. Data from the three GMP monitoring events, weekly TOD data, and supplemental USGS data were used to develop water-table maps and cross-sections in this area. The wells used in these evaluations are shown in Figure 5.23.

Limited data are available for the confined flow system at the NWBCS, since the majority of the wells near the NWBCS are screened in alluvium. Only two well clusters south of the barrier wall exist in this area that include wells screened in the confined flow system. Although 1992 water-level data show that downward vertical gradients exist between the unconfined/confined flow systems at this location, unconfined/confined aquifer interaction has not been identified as a concern (Stollar et al., 1991). Therefore, the following analysis of the impact of the NWBCS on groundwater flow was restricted to the unconfined flow system.

5.3.1.1 <u>Water-Table Maps</u>

Figures 5.2 through 5.4 illustrate the configuration of the water-table using a 2-foot contour interval to detail the effects of the NWBCS on groundwater flow in this area. The general configuration of the water-table remained similar to that shown for the 1991 CMP.

Gradients are steep along the northeastern extension due to the high elevation and the slope of the bedrock surface in this area. Groundwater flows closely follow the bedrock surface in a northeast to southwest direction that parallels the barrier wall at a gradient of approximately 0.03. This is also consistent with southwestern topographical grades and bedrock surface slope direction. Flow is toward the southwestern end of the wall which indicates more efficient recharge and/or less water being directed toward the central portion of the wall because of operations. During the Winter quarter, a general flattening of the water-table was apparent in the central and southwest portion of the barrier wall. A reversal in hydraulic gradient to the southeast was apparent in the central portion of the wall but was not achieved in the area of the southwest extension or the northeastern extension.

During the Spring quarter, the water-table surface was similar to Winter, except for a slight decline (one to two feet) in water-level elevations from up and downgradient wells near the southwestern end of the barrier wall. This indicates that drawdown from the extraction wells is being achieved in this area. A reversal in hydraulic gradient was only apparent around the central portion of the wall.

The water-table configuration during the Summer quarter was slightly different than the first two quarters. The southwestern portion of the barrier wall was characterized by a closed low area roughly trending northwest-southeast slightly across and upgradient (southeast) of the central portion of the wall. Head elevations immediately north of the wall were generally one to two feet higher than heads south of the wall along the central portion of the system. The northeastern 1,000 feet was, again, similar to previous quarters with gradients to the southwest and parallel to wall, but at a somewhat lower value (approximately 0.014).

In summary, the water-table maps illustrate that recharge downgradient of the barrier wall was sufficient to produce a small reversal in hydraulic gradient along the central portion of the barrier wall during the three monitoring quarters.

5.3.1.2 Water-level Cross-Sections

Cross-sections illustrating the water-table configuration both northwest and southeast of the barrier wall were prepared for three quarters of the 1992 monitoring year (Figures 5.24 through 5.26). Available water-level data for the second quarter did not provide sufficient areal well coverage to interpolate the potentiometric surface between well locations. Water-levels southeast of the barrier wall were projected less than ten feet and those northwest of the barrier wall were projected approximately 350 feet. These projected data were not corrected to account for lateral gradients in this area. Water-level elevations shown on the cross-sections are averaged values of all water-level data collected during the respective quarter for a specific well.

The cross-sections illustrate that a reversal in hydraulic gradient to the southeast existed along the original central portion of the barrier wall during the 1992 water monitoring year. Head differences in this area were fairly consistent for the three quarters shown and ranged from 0.5-foot to greater than nine feet higher downgradient of the wall in the fourth quarter. Lateral hydraulic gradients were to the southeast and ranged from 0.001 to 0.02. Head differences across the hydraulic barrier were less than 0.1-foot during the first quarter. Water-level data from wells downgradient of the barrier were not available to interpolate gradient conditions during the third and fourth quarters. The small gradient reversal shown in this area are similar to conditions reported during the 1991 water monitoring year.

As shown on the cross-sections and water-table maps, a reversal in hydraulic gradient was not achieved during the 1992 water monitoring year along the northeastern extension that was constructed in 1990. Lateral gradients in this area were 0.001 to 0.02 to the southwest. Hydraulic gradient reversals in this area were also not achieved during the 1991 water monitoring year. However, operations data and the cross-sections show that water-levels are high on the dewatered side of the barrier due to a bedrock high and the upstream monitoring well installed in this area is out of context with the hydrologic system. The apparent lack of reversal is an artifact of the well elevation.

5.3.2 Contaminant Migration

Contaminant migration in the vicinity of the NWBCS were assessed by comparing recent and historical GMP data from wells screened in the unconfined flow system near the barrier.

These data were evaluated through the use of concentration histograms. Figures 5.27 through 5.30 present histograms that graphically display contaminant concentrations through time for selected wells screened in the unconfined flow system at the NWBCS. The wells selected for presentation vary between figures because the data sets for each compound varied. Fluoride analyses were not performed for samples from wells selected for histogram presentation.

DIMP analytical data, accumulated from 1978 to the present, are graphically displayed as histograms for twenty-one wells near the NWBCS (Figure 5.27). 1992 GMP data was available for twelve of these wells. Both off-post and southeast of the barrier, DIMP has diminished in concentration since system startup. DIMP was not detected in any samples in the NWBCS area during the 1992 water monitoring year. The high CRLs shown in 1992 on the histograms reflect a different method and laboratory than was previously used for DIMP analyses. For the 1992 water monitoring year, samples were analyzed using Army-certified methods for the first half of the year, and USEPA SW846 methods during the fourth quarter.

Figure 5.28 presents historical DBCP data for twenty-one wells near the NWBCS. DBCP analyses were performed for twelve of these wells during 1992. DBCP concentrations for all wells, except 37334, have not been detected since 1990 or startup of the slurry wall extension. Upgradient of the NWBCS, samples from several wells have reported no detections of DBCP since sampling was initiated. Samples from wells downgradient of the barrier wall have historically either shown no detections or sporadic detections that do not illustrate a trend for DBCP contamination. DBCP was detected in Well 37344, located off-post and downgradient of the barrier wall, during 1991 but was not detected in this well during the two sampling events in 1992.

Historical and recent dieldrin levels are illustrated for samples from twenty-seven wells in Figure 5.29. Dieldrin analytical results are shown for seventeen of these wells for the 1992 water monitoring year. Dieldrin detections had been observed in some wells southeast of the barrier wall since monitoring began in 1978. Recent data (since 1990) show that dieldrin in these wells have generally been consistently not detected, except for samples from Wells 22016 and 22019 which showed a very slight increase above the CRL. A low-level of dieldrin was reported in downgradient Well 37332 in 1991, but was not detected during the three sampling events in 1992. Concentrations of dieldrin in samples downgradient and northwest of the wall were either not detected or at concentration levels <0.1 μg/l, with the exception of Well 37333. Dieldrin was not reported in samples from this well until 1986, from

which time it has been consistently detected at low levels but with decreases in concentration after 1988. During 1992, dieldrin was detected in samples from 37333 during the second and third quarters at concentrations of 1.1 μg/l and less, but was not detected during the fourth quarter. In general, dieldrin levels in downgradient and offpost wells are similar to or less than historical levels since startup of the barrier wall extension. Available data demonstrate that NWBCS operations have been effective in mitigating downgradient dieldrin migration.

Figure 5.30 shows chloroform analytical data collected from 1985 through 1992 for fifteen wells surrounding the NWBCS. Chloroform analyses were performed for eight of the wells shown on Figure 5.31 during 1992. Data from wells downgradient of the barrier wall indicate that chloroform concentrations have generally decreased since 1985. Offpost Well 37335 displayed a slight isolated increase to 2.3 μg/l, above historical nondetect levels since 1987. Available data from wells to the southeast also show a general declining trend with the exception of an isolated increase in chloroform in Well 27086. These slight increases in chloroform appear anomalous and, at these levels, may be sampling or laboratory contaminant artifacts.

5.4 BASIN F INTERIM RESPONSE ACTION AREA

Basin F was a lined evaporation basin that existed in Section 26 and was excavated as part of the Basin F IRA during 1988 and 1989. The Basin F IRA provided for the construction of temporary containment structures to hold contaminated liquid, soil, settled solids, liner material, and overburden from the excavation activities. The Basin F area contains the following structures: a 92.7-acre surface depression that has been excavated and covered with a contoured low-permeability clay cap; a 16-acre double-lined, enclosed waste pile within the historic perimeter of the basin; a double-lined collection pond adjacent to the waste pile leachate; two double-lined liquid storage ponds immediately north of the basin; and three lined carbon steel holding tanks east of the basin.

The following subsections summarize 1992 GMP groundwater flow and analytical data. A detailed discussion of the Winter 1992 and contaminant distribution in the Basin F area were presented in Section 4.0. The major findings from subsection 4.3.2 regarding lateral contaminant migration are briefly summarized below, as well as an assessment of vertical contaminant distribution using available Winter 1992 data.

5.4.1 Groundwater Flow

Data from three GMP water-level measurement events were used in the evaluation of groundwater flow in the Basin F IRA area. The configuration of the water-table in the Basin F area for the 1992 monitoring quarters (Figures 5.2 through 5.4) is similar to the 1991 CMP quarterly water-table contour maps. Groundwater flow in this area is significantly influenced by the hydraulic conductivity and slope of the bedrock. Approximately two-thirds of the alluvium in Section 26 is unsaturated (see Figure 2.4) and flow occurs in the upper portion of the Denver Formation. The hydraulic gradient in the Denver Formation is generally steeper in areas of unsaturated alluvium (HLA, 1992b). This probably reflects the lower hydraulic conductivity of the Denver Formation relative to the alluvium.

Groundwater flow in the Basin F area is characterized by a northwest-trending groundwater divide in the west-central portion of Section 26. Northeast of the divide, groundwater flow is to the north and northeast. Southwest of the divide, groundwater flow is to the northwest.

Water-levels were one to three feet higher in some wells during the Winter quarter as compared to the Spring and Summer water-level data. Fluctuations between the Spring and Summer quarters were generally less than one foot. Water-levels in the Basin F IRA area were similar to 1990 through 1991 CMP data, except for the northern portions of Section 26. This area exhibited water-levels approximately 2 to 4 feet lower during the 1990 CMP. Changes in this area are primarily the result of resurveyed well reference points (HLA, 1992b). Ground elevations were adjusted for some wells in the northern portions of Section 26, causing changes in contour configurations.

5.4.2 Contaminant Migration

Contaminant migration in the Basin F IRA area was evaluated in subsection 4.3.2 through the use of histograms and contaminant distribution maps for the unconfined and confined flow systems. The following discussion summarizes the lateral and vertical extent of DIMP, DBCP, dieldrin, chloroform, and fluoride in the unconfined and confined flow system.

5.4.2.1 Lateral Extent of Contamination

Contaminant plumes in the unconfined flow system covering the greatest lateral area extend from the South Plants to the Basin A area and from the Basin F area north of the RMA

(Figures 4.5 through Figure 4.24). The primary contaminant flow paths in the unconfined system are related to the presence and orientation of alluvium that fills paleochannels incised in the Denver Formation (Stollar et al., 1991).

Most GMP target analytes were detected in the Basin F area (Tables 4.18 through 4.20). As shown on the plume maps and histograms (Figures 4.5 through 4.19), these contaminants migrate primarily in a north-northeast direction toward the NBCS. Contaminant migration within the Basin F pathway occurs in saturated alluvium and the weathered portion of the unconfined Denver Formation (Stollar et al., 1990b).

The areal distribution of DIMP in the unconfined flow system in the Basin F area has not changed significantly since Fall 1989. Figure 4.5 illustrates Fall 1989 DIMP plumes in the unconfined flow system with Winter 1992 analytical data posted. The major discrepancies noted on the plume map in Sections 23 and 26 reflect the addition of five reclassified confined Denver flow systems wells to the unconfined flow system sampling network. Histograms of DIMP concentrations (Figure 4.6) show generally decreasing to static concentrations from wells that have been monitored since 1978. Two wells located in Section 23 displayed isolated increases during the Summer 1992 monitoring event. Future analytical data collected for these wells will determine whether these increases are anomalous.

DIMP was only reported in one confined flow system well (26129) sampled during the Winter 1992 quarter at a concentration level of 1800 μg/l. This indicates that DIMP contamination in the confined flow system in the Basin F area appears restricted to a small area in Section 26 near the north end of Basin C. However, there is incomplete well construction information for Well 26129 and water-quality data from this well may be suspect. Winter 1992 DIMP levels are comparable with historical water-quality data reported for confined flow system wells in the Basin F area and illustrate consistent water-quality conditions in the confined flow system that have not changed significantly since 1989. (Figure 4.7).

The configuration of the DBCP plume extending northeast from the northern Basin F area has not changed significantly since Fall 1989 (Figure 4.8). 1992 GMP DBCP values from two wells in Section 23 exhibit concentration levels above that previously mapped for their location. Incorporating data from these wells extends the central DBCP plume slightly further north-northeast than interpreted from previous CMP data. Histograms for DBCP (Figure 4.9) show slight concentration increases in Wells 26157 and 26133, located east of the temporary storage ponds, when compared to Fall 1989 levels. However, in general, DBCP levels have remained

fairly constant since monitoring began and do not display a clear change since initiation of Basin F IRA activities in 1988.

DBCP was not detected in any confined flow system samples analyzed during the Winter 1992 sampling event (Figure 4.10) DBCP has consistently not been detected in the confined flow system in the Basin F area for the wells shown in Figure 4.10 for the past two years.

Figure 4.11 illustrates Fall 1989 dieldrin plumes with Winter 1992 analytical results superimposed. A number of wells in Section 23 and 26 displayed slightly increased dieldrin levels above the contoured concentration range shown on Figure 4.11. Many of these slight deviations may be due to the laboratory dieldrin spectral analysis and cross-contamination problems discussed in subsection 4.3.1. Four reclassified confined flow system wells exhibit concentrations less than the CRL or within an order of magnitude below the contoured concentration range. Histograms of dieldrin concentrations (Figure 4.12) illustrate that samples from all the wells shown have reported dieldrin detections of less than 2.0 μg/l since 1988 , with isolated, erratic increases in no apparent areal pattern.

Low levels of dieldrin were reported in confined flow system samples from three wells in Section 26 and one well in Section 23 during the Winter 1992 quarter (Figure 4.13). Dieldrin had been reported in one of these Section 26 wells at slightly higher concentration during Fall 1989. The other two low-level detections in Section 26 were from wells that reported dieldrin as less than the CRL during the 1990 and 1991 CMP. The isolated dieldrin detection in Section 23, downgradient of the Basin F area, is consistent with historical levels for that well.

Figure 4.14 illustrates the Fall 1989 chloroform plume with superimposed Winter 1992 analytical data. Winter 1992 chloroform distributions remained similar to historical CMP data. The primary differences are related to the addition of reclassified confined flow system wells to the Fall 1989 plume map. Three reclassified wells (23180, 23189, and 23221) in Section 23 and one well in Section 26 (26149) exhibit concentrations below the CRL or significantly below the contoured concentration range for their locations. Chloroform concentration histograms (Figure 4.15) illustrate fairly consistent water-quality conditions for most wells located northwest of the solid waste pile. Quarterly concentration increases and decreases relative to historical data are observed in individual wells located north and east of the temporary storage pond. Chloroform levels in Well 26085 have steadily declined since 1990.

Chloroform was not detected in any confined flow system wells sampled during Winter 1992 (Figure 4.16). The lack of chloroform detections in these wells are consistent with

historical data for confined flow system wells and reflect groundwater conditions that have remained relatively constant for chloroform in this area.

Figure 4.17 illustrates Fall 1989 fluoride plumes with Winter 1992 detections posted. In general, fluoride data show a decreasing trend in concentration levels for all wells monitored during 1992, as compared to 1991 and 1990. All of the reclassified confined flow system wells display fluoride concentrations similar to or less than that contoured on the plume map, with the exception of Well 26066. Histograms of fluoride concentrations are presented in Figure 4.18. The histograms illustrate that fluoride levels fluctuate quarterly in an apparent random pattern in the Basin F IRA area. However, the 1992 GMP data show lower levels of fluoride when compared to previous years.

Figure 4.19 shows Winter 1992 fluoride detections in samples from the confined flow system. Changes in overall fluoride distribution within the confined Denver Formation remained relatively minor, with the exception of one well in Section 26 (26153). The Winter 1992 fluoride concentration for Well 26153 was 2830 μg/l, but was reported as below the CRL for Fall 1989 and Winter 1991. This increase may be anomalous or may just be a reflection of natural background fluctuations.

5.4.2.2 Vertical Extent of Contamination

The occurrence of DIMP, DBCP, dieldrin, chloroform, and fluoride were examined in the confined flow system to evaluate vertical contaminant migration between the unconfined and confined flow system. The vertical distribution of DIMP, DBCP, dieldrin, chloroform, and fluoride from all confined flow system wells in the vicinity of unconfined flow system contaminant plumes were evaluated.

The presence of DIMP, DBCP, dieldrin, and chloroform in the confined flow system suggests vertical migration of contaminated groundwater, since these are not naturally occurring compounds. Although fluoride is a naturally occurring constituent of groundwater at RMA, elevated detections above background levels may indicate vertical interaction between the unconfined and confined flow systems.

Table 5.3 summarizes confined and unconfined Denver flow system detections for the selected analytes. All detections of fluoride above 2,000 μg/l were considered in this assessment. The results are presented for each analyte by well number and screened interval. Depth of contamination at each well was interpreted to be the depth below ground surface of

the bottom of the screened interval.

DIMP, dieldrin, and fluoride detections in the confined flow system indicate that aquifer interaction likely occurs in a downward direction. Vertical gradient directions for unconfined-/confined well cluster sites (Table 4.4) in the Basin F area also show a predominant downward direction. The analyte detections occurred in wells screened beneath areas of unconfined flow system contamination.

DIMP has been consistently detected at concentrations between 1700 to 1900 μg/l in Well 26129 since 1989. This lack of DIMP detections in all wells but 26129 indicates that vertical movement is restricted to an area around Well 26129 and may possibly be due to poor well construction (as discussed in subsection 5.4.2.1).

Many of the low-level dieldrin concentrations reported in the confined flow system were slightly above historical dieldrin levels or were from wells that have previously shown no detections. As described in Section 4.3.1, dieldrin laboratory and sampling method QC problems may have contributed to some of these low-level detections for the 1992 data set. The deepest dieldrin detection from Well 26142, at a depth of 146 feet below ground surface, was also reported during the Fall 1989 sampling event, and demonstrates a historical basis for slight dieldrin contamination in the confined flow system.

Confined flow system fluoride concentrations above 2,000 μg/l occur both within and outside of unconfined flow system plume locations, indicating that background concentrations of fluoride may be higher in the Denver Formation than in the alluvium.

Interpretation of the vertical distribution of contaminants is complicated by the presence of variable lithologies and lateral discontinuities throughout the alluvium and Denver Formation at RMA. In general, the horizontal component of flow predominates over the vertical component. Thus, contamination is generally limited in extent and lower in concentration in the confined flow system.

5.5 BASIN A NECK CONTAINMENT SYSTEM

The BANS IRA began operation in Spring 1990. MKE constructed the BANS to intercept and treat contaminated groundwater migrating from Basin A through the Basin A Neck paleochannel.

The BANS is composed of seven alluvial extraction wells in a northeast-southwest alignment across the Basin A Neck paleochannel perpendicular to the alluvial groundwater flow.

Downgradient of the alluvial extraction well array is a soil-bentonite barrier wall that extends approximately 320 feet along a northeast-southwest alignment across the narrowest portion of the Basin A neck. Groundwater treatment at the BANS consists of using activated carbon to remove organic contaminants.

Three gravel-filled recharge trenches are located downgradient of the barrier wall and extend approximately 540 feet parallel to the barrier wall. Treated groundwater is recharged to the trenches in the unconfined flow system, with the goal of establishing a localized reverse gradient along the barrier wall.

The BANS was designed for a maximum flow rate of 32 gallons per minute (gpm) with average flows of less than 18 gpm. During the 1991 water monitoring year, average flow intercepted, treated, and recharged at the BANS was approximately 12 gpm. This amount compares closely to groundwater flow rates that were estimated for the Preliminary Engineering Design Package for the Basin A Neck Groundwater Intercept and Treatment System Interim Response Action (MKE, 1989). MKE estimated that flow through the Basin A Neck was 14 gpm.

In addition to the groundwater flowing through the Basin A Neck, water from the IRA for the Groundwater Intercept and Treatment System North of Basin F at RMA was transferred to the Basin A Neck treatment facility. During the 1991 and 1992 water monitoring years, groundwater extracted from North of Basin F was transferred by pipeline to the BANS and air stripped before entering BANS influent sump.

A detailed assessment of the hydrologic conditions at the BANS was not possible because of limited available water-level data. Water-level data collected in this area was plotted on the contour maps produced for the three 1992 GMP monitoring events to evaluate the local effects of the BANS on the unconfined groundwater flow system. Figure 5.1 shows the locations of wells used for water-level measurements during the 1992 GMP.

The unconfined flow system water-table elevation maps, Figures 5.2 to 5.4, show small seasonal variations in water-table elevations. Summer water-levels for some wells were one to two feet higher than that observed during the Winter quarter. The configuration of the water-table during the 1992 GMP is similar to conditions shown during 1991 CMP monitoring events and previous years. Because of limited water-quality monitoring at the BANS, it was not possible to fully evaluate the effectiveness of the system in mitigating contaminant migration. Groundwater samples were collected by MKE from three wells located in the vicinity of BANS

during the fourth quarter of 1992. Table 5.4 summarizes analytical results for the selected analytes of concern. Fluoride analyses were not performed for samples collected in this area.

5.6 IRONDALE CONTAINMENT/TREATMENT SYSTEM

The ICS is a system of extraction wells, recharge wells, and a treatment system that forms a hydraulic barrier to offpost groundwater flow. It was designed to prevent the offsite migration of DBCP. The original system, completed in 1981, consisted of two rows of 33 dewatering wells and one row of 14 recharge wells. During the 1989/1990 period, the system was modified to include a total of 38 extraction wells and 22 recharge wells (MKE, 1992). The system is operated by Shell.

During 1990, Shell installed and sampled five new monitoring wells near the southern end of the ICS. These wells were installed to prevent the offpost South Adams County Water and Sanitation District (SACWSD) well from having an affect on the DBCP plume. During 1991, system modifications were completed to stop this bypass.

Because of limited monitoring at the ICS, it was not possible to fully evaluate the effectiveness of this system in mitigating offsite contaminant migration. Although Shell periodically prepares such assessments, the 1992 data was not available for review in the RMAED at the time of this writing.

The areal density of potentiometric data in this area for 1992 was not adequate to construct cross-sections of the water-table surface in this area. Therefore, groundwater flow in the area of the ICS was only evaluated through the use of water-table maps only. Water-levels were measured at the well locations shown in Figure 5.24. Water-table maps (Figures 5.2 through 5.4) were generated for each of the three 1992 GMP monitoring events.

During the Winter quarter, the water-table configuration was characterized by a mound centered around the recharge wells. The effect of the mound was to produce a reversal in hydraulic gradient (i.e., from northwest to southeast). The gradient to the southeast was approximately 0.016.

During the Spring quarter, a similar mound was evident, but greater in extent and with higher water-levels. The gradient in this area was to the southeast ranging from approximately 0.01 to 0.02. Water-levels were one to four feet higher than the Winter quarter in an area southwest of the ICS.

The water-table map for the Summer quarter shows a similar mounding configuration to

that observed during the Winter and Spring quarters, except that the mound was much more limited in extent and water-levels were nine feet lower near the center of the mound, as compared to the Spring quarter. Water-levels in wells located southwest of the ICS also exhibited a four to eight foot decline in water elevation. This may be the result of pumping from SACWSD wells in this area. A moderate gradient southeast of the ICS, toward this water-table low, is shown during the three 1992 GMP monitoring events.

5.7 CONCLUSIONS

The following conclusions regarding the effect of IRA remediation activities on groundwater flow patterns and contaminant migration in the vicinity of the NBCS, NWBCS, and Basin F IRA project areas are listed below. A detailed assessment of the effect of IRA activities on groundwater flow and contaminant migration at BANS and the ICS was not possible due to limited available hydrologic and analytical data.

5.7.1 North Boundary Containment System IRA

1. Water-level data demonstrates that a reversal in hydraulic gradient to the south at the NBCS was achieved throughout the length of the most of the system during the 1992 water monitoring year. A reversal did not occur along the eastern 1,200 feet of the barrier wall during the Winter quarter, but was achieved in this area during the Spring and Summer quarters.

2. Limited water-level data for confined flow system wells were available for the 1992 water monitoring year. Available data for two sets of wells on opposite sides of the barrier wall show a normal (northward) regional gradient during the Winter and Spring quarters and a slight reversal during the Summer monitoring event. Small hydraulic head differences between these wells illustrates that gradients between confined wells screened in different zones tend to change as a result of seasonal or normal fluctuations in the data.

3. Available data for unconfined/confined well cluster sites show predominate downward hydraulic gradients between unconfined/confined flow system well pairs north of the barrier wall during the three GMP monitoring events. A slight upward gradient existed between unconfined alluvial/Denver Formation well sites south of the barrier wall for most of the 1992 water monitoring year. Upward gradients in this area are favorable in that they impede downward contaminant migration to the confined flow system. These upward gradients were also observed during the 1991 CMP.

4. Analytical data for unconfined flow system wells located north of the barrier wall

demonstrate that concentrations of mobile contaminants such as DIMP, chloroform, and DBCP have decreased significantly and NBCS operations have been effective in preventing downgradient contaminant migration. Available data for dieldrin, a relatively immobile contaminant, show very low (<1 μg/l) to nondetect levels in wells downgradient and in the immediate vicinity of the NBCS barrier wall. NBCS operations have been effective in preventing downgradient (northward) dieldrin migration, as illustrated by the higher concentrations south of the NBCS. Fluoride analyses were not performed in this area during the 1992 water monitoring year.

5.7.2 Northwest Boundary Containment System IRA

1. Recharge downgradient of the barrier wall was sufficient to maintain a reversal in hydraulic gradient during the 1992 water monitoring year. A slight gradient reversal was also maintained across the southwest extension. A reversal in hydraulic gradient was not apparent along the northeastern barrier wall extension, due to the elevation of the monitoring well on the upstream side.

2. The limited analytical data collected during the 1992 water monitoring year for unconfined flow system wells show that DIMP, DBCP, chloroform, and dieldrin concentrations downgradient of the NWBCS have either declined or remained unchanged since startup of operations and the barrier wall extension in 1990. DIMP and DBCP were not detected in any of upgradient or downgradient wells sampled during the 1992 monitoring events. Isolated low-level increases in chloroform were minor and below treatment criteria. Likewise, dieldrin analyses from wells downgradient and offpost either remained similar to or less that historical data. These wells exhibited dieldrin levels that were either nondetect or slightly above the CRL.

5.7.3 Basin F IRA

1. The 1992 GMP water-table surface showed very little change in configuration between monitoring events and remained similar to the 1991 CMP quarterly configuration. Groundwater flow in this area is characterized by a northwest trending groundwater divide in the west-central portion of Section 26. Water-levels were one to three feet higher in some wells during the Winter quarter. Fluctuations between the Spring and Summer quarters were generally less than one-foot.

2. Unconfined and confined flow system analytical data for DIMP, DBCP, chloroform, and dieldrin show decreasing to relatively unchanged concentration levels in most Section 23 and 26 wells since completion of Basin F excavation in 1989. Isolated quarterly fluctuations in concentrations of these contaminants occur in some wells. However, the data generally reflects consistent groundwater quality conditions for this area. Histograms of dieldrin concentrations illustrate that samples from most of these wells have reported

dieldrin detections of less than 2.0 μg/l since 1988, with isolated, erratic increases in no apparent areal pattern. The data are inconclusive regarding the effect of Basin F IRA activities on dieldrin levels. Fluoride data in the Basin F area has typically shown random fluctuations without a clear trend. The 1992 GMP data show diminished fluoride levels for all unconfined flow system wells when compared to previous years. Data package review of select fluoride analyses show chloride interference that may have resulted in increased fluoride concentrations.

3. Only one detection of DIMP in an upgradient well and four dieldrin detections up and downgradient of Basin F in Section 26 were reported for 1992 GMP confined flow system wells. The presence of DIMP and dieldrin in the confined flow system may be a function of poor well construction for Well 26129 that could be providing a pathway for vertical movement. Dieldrin analyses were consistent with historical data, except for increased concentration levels in two wells that have historically shown dieldrin at less than the CRL. Elevated levels of fluoride above background were also shown, but these occurred both within and outside of unconfined flow system contamination. This indicates that background concentrations of fluoride may be higher in the Denver Formation than in the alluvium and subject to natural variations.

6.0 DOMESTIC WELL SAMPLING RESULTS

Residential tap water sampling was conducted by the Tri-County Health Department (TCHD) during the four quarters of the 1992 water monitoring year. A total of 124 domestic well water samples and thirty-seven QA/QC samples were collected by TCHD . Table 6.1 summarizes the TCHD sampling effort. The domestic well sampling locations and well ID numbers are shown on Figure 6.1. All tap water analytical data is provided on diskette in Appendix B.

6.1 CHEMICAL ANALYSIS

The offpost investigative tap water samples collected by TCHD were analyzed for the same analytical suite as the onpost investigative samples collected by the Army (see Table 1.2). Fourteen samples collected during the Fall 1992 sampling round were also analyzed for NDMA. PMRMA-certified analytical methods were used for these analyses, as shown in Table 3.3. The tap water samples were analyzed at ESE and Datachem laboratories. A summary of the tap well data rejected for QA reasons is presented in Table 6.2.

The following summarizes field and laboratory problems that influenced data results and which should be considered in data interpretations:

- No data were reported for nitrogen-phosphorus pesticides or organosulfur compounds for the following sites: 1178B, 410A, 411A, 542A, 609A, and 614A. These analyses were canceled at the laboratory by the Harding Lawson Associates QC coordinator because of QC problems.

- Results for the Fall 1991 cyanide analyses were rejected because of improper sample preservation for wells 299A, 299A-D(duplicate), 359A, 372A, 540A, 550A, 551A, 555A, 578A, 578B, 602A, 602A-D(duplicate), 602A-FB(field blank), 603A, 984A, 1060A, 1302A, and 1305A. These samples were received by the laboratory with a pH less than the required value of 12. The GC/MS volatile analysis for the sample collected from 1178B was rejected because the holding time was exceeded.

- The full analytical suite was not performed for samples from Well 332C (Fall 1991 sampling round) because the samples arrived at the laboratory at a higher temperature than the required 4 degrees Celsius. Only the volatile hydrocarbon compounds and agent products for this sample were analyzed. A duplicate

sample container from Well 332 was broken at the laboratory prior to sample extraction and the sample was not analyzed for agent products.

6.2 ANALYTICAL RESULTS

Tables 6.3 through 6.6 summarize the residential tap water sample analytical results for GMP target analytes. This data is presented in tabulated form.

7.0 GLOSSARY

>	greater than
<	less than
1,1,1-TCE	1,1,1-trichloroethane
AA	atomic absorption spectrometry
ALDRN	aldrin
Army	U.S. Department of the Army
AS	arsenic
BANS	Basin A Neck Groundwater Intercept and Treatment System
CF&I	Colorado Fuel and Iron Corporation
CFS	confined flow system
CH2CL2	methylene chloride
CHCL3	chloroform
CLC6H5	chlorobenzene
CLP	Contract Laboratory Program
CMP	Comprehensive Monitoring Program
COC	chain-of-custody
CPMS	p-chlorophenylmethyl sulfide
CQAP	Chemical Quality Assurance Plan
CR	chromium
CRL	certified reporting limit
CU	copper
CWP	Composite Well Program
DataChem	DataChem Laboratories

DBCP	dibromochloropropane
DCPD	dicyclopentadiene
DDT	dichlorodiphenyltrichloroethane
DIMP	diisopropylmethylphosphonate
DMMP	dimethylmethylphosponate
DLDRN	dieldrin
DQO	data quality objectives
Ebasco	Ebasco Services, Inc.
ENDRN	endrin
EPA	Environmental Protection Agency
ESE	Environmental Science and Engineering, Inc.
F	fluoride
Ft	feet
GB	isopropylmethyl fluorophosphonate
GC/FID	gas chromatography/flame ionization detector
GC/PID	gas chromatography/photoionization detector
GC/ECD	gas chromatography/electron capture detector
GC/MS	gas chromatography/mass spectrometry
GC/CON	gas chromatography/conductivity detector
GC/NPD	gas chromatography/nitrogen phosphorus detector
GC/FPD	gas chromatography/flame photometric detector
GMP	Groundwater Monitoring Program
gpm	gallons per minute
H	Levinstein mustard

HG	mercury
HLA	Harding Lawson Associates
HPLC	high performance liquid chromatography
Hyman	Julius Hyman and Company
ICP	inductively coupled argon plasma screen
ICS	Irondale Containment/Treatment System
ID	identification
IONCHROM	ion chromatography
IRA	interim response action
ISP	Initial Screening Program
LSD	Laboratory Support Division
LT	less than Certified Reporting Limit
MIBK	methylisobutyl ketone
mg/l	milligrams per liter
MKE	Morrison-Knudsen Engineers, Inc.
N/A	not applicable
NBCS	North Boundary Containment/Treatment System
NDMA	n-Nitrosodimethylamire
NS	not sampled
NWBCS	Northwest Boundary Containment/Treatment System
OAS	Organizations and State
PARCC	Precision, Accuracy, Representativeness, Comparability, and Completeness
PMRMA	Program Manager for Rocky Mountain Arsenal
PPB	parts per billion

PPDDT	2,2-bis(para-chlorophenyl)-1,1,1-trichloroethane
PWT	Pacific Western Technologies, Ltd.
QA/QC	quality assurance and quality control
RI/FS	remedial investigation/feasibility study
RMA	Rocky Mountain Arsenal
RMAED	RMA Environmental Database
RPD	relative percent difference
RTIC	Rocky Mountain Arsenal Technical Information Center
SACWSD	South Adams County Water and Sanitation District
Sarin	isopropylmethyl fluorophosphonate
Shell	Shell Oil Company
Stollar	R.L. Stollar and Associates, Inc.
TCHD	Tri-County Health Department
TCLEE	tetrachloroethene
TIC	tentatively identified compound
TOC	top of (well) casing
TOD	Technical Operations Division
UFS	unconfined flow system
UNK	unknown compound
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
ZN	zinc
μg/l	micrograms per liter

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